VOL. 1

United States of America,
Northern District of Illinois, } ss.
Eastern Division.

IN THE

District Court of the United States

UNITED STATES OF AMERICA, *Complainant,* vs. THE SANITARY DISTRICT OF CHICAGO, *Defendant,*	C. C. No. 29,019, and Equity No. 114.

RECORD OF TESTIMONY AND PROOF TAKEN BEFORE COMMISSIONERS APPOINTED TO TAKE TESTIMONY IN SAID CAUSE.

Appearances:

Mr. James H. Wilkerson,
United States Attorney, and
Mr. Albert L. Hopkins,
Assistant United States Attorney,
For Complainant.

Mr. Edmund D. Adcock and
Mr. Alfred S. Austrian,
For Respondent.

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GENERAL INDEX TO WITNESSES.

VOL. I–VI.

Complainants.

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Part 2.

Defendants.

Note 1.—Volume IV (pages 1813-2628) consists of extracts from testimony and historical data in the case of United States vs. Economy Light and Power Company, and historical data from Brown's Drainage Canal; the Report of the Illinois and Michigan Canal Commissioners for the year 1900; Andreas' History of Chicago and extracts from reports of United States Engineers and certain other public documents introduced by The Sanitary District of Chicago.

Note 2.—Pages 3601 to 3765, inclusive, of Volume VI, contain the following: Extracts from a public hearing on February 28, 1912, in connection with the application of the Sanitary District of Chicago, dated February 5, 1912, for permission to divert 10,000 cu. ft. per second of water through the Chicago and Calumet Rivers; extracts from a public hearing in connection with the same application on March 27, 1912, at which representatives of the Canadian Government and various Canadian cities and interests were heard; extracts from briefs and memoranda submitted; and also certain letters, telegrams, resolutions of protest from various states, cities, chambers of commerce, associations, and individuals located on the Great Lakes and in the Illinois River valley.

SPECIAL INDEX TO WITNESSES.

IN VOLUME ONE

Complainants

Defendants.

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UNITED STATES OF AMERICA, *Complainant,* *vs.* **THE SANITARY DISTRICT OF CHICAGO,** *Defendant,*	**C. C. No. 29,019.**

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New York, February 15, 1909.

Deposition of Alfred Noble of New York City, taken before John A. Shields, Esq., United States Commissioner, pursuant to stipulation hereto attached.

Appearances:

James H. Wilkerson, Esq., Frank R. Reid, Esq., for the United States of America.

John C. Williams, Esq., for Sanitary District of Chicago.

ALFRED NOBLE, being duly sworn, testified as follows:

Examined by Mr. Wilkerson.

Q. What is your full name?
A. Alfred Noble.
Q. Where do you live?
A. New York.

Q. What is your address, residence address?
A. Residence, 501 West 120th.
Q. And your office address?
A. 315 Fifth avenue.
Q. What is your business?
A. Civil engineer.
Q. What position do you now hold, if any?
A. Chief engineer of the East River Division of the Pennsylvania Tunnel & Terminal R. R. Co.
Q. How long have you held that position?
A. About seven years.
Q. What has been the scope of your work in that position?
A. Well, it comprises in the first place the excavation of the Pennsylvania station between 9th and 7th avenues, and the construction of a retaining wall around the site and the building of tunnels from a short distance east of 7th avenue to Long Island City and the approaches and the terminal yard connected therewith.
Q. That has occupied the principal part of your time during the period mentioned?
A. Yes.
Q. Have you been engaged in any other work?
A. I was a member of the consulting board for the Panama Canal.
Q. What was the scope of your duties in that position?
A. To make a recommendation as to whether the sea level or summit level canal should be adopted.
Q. During what period were you occupied with that work?
A. For four or five months into the fall and early winter—fall of 1905 and early winter following.
Q. Prior to your taking your present position in what work as engineer were you engaged—what position did you fill in a general way?
A. I was in charge, local charge of the St. Mary's Falls Canal and River.
Q. During what year?
A. 1870 to '82. I was then on various bridge works as resident and assistant chief engineer for about 10 years—for about 12 years. I was a member of the Nicaragua Canal Board in 1905 and of the United States board of engineers and deep waterways from '97 to 1901, and with the Isthmian Canal Commission from '89 to 1902 or '03.
Q. With reference to the positions in which your duties brought you in contact with the Great Lakes, I wish you would

state a little more in detail just *what* the scope of your work was and what—in a general way what line of work you did?

A. The St. Mary's Falls Canal had been built by the State of Michigan and paid for by land-grant made by the United States and opened for navigation in '55, and the general government took in hand in 1870 the enlargement of the canal and the building of a new lock and sundry improvements in the river channels to obtain a greater depth for navigation.

Q. Well, you had some other positions, had you not, which brought you in contact with work in connection with the lakes?

A. I was a member of the board of engineers on deep waterways, charged with the duty of surveying a ship canal route from the lakes to tidewater.

Q. During what period?

A. That was from '97 to about '01.

Q. I would like to have you state a little in detail the general nature of your work in that connection.

A. The principal part of the work was in surveying routes from Lake Erie, one from Lake Erie to Lake Ontario and from Lake Ontario there were two routes, one ascending to the Oswego River and crossing over the summit to the Mohawk at Rome and on the Mohawk to Schenectady, and thence across country to a point on the Hudson River a little below Albany, together with an alternative route from the Mohawk all the way down to the Hudson River and continuing far enough down the river to obtain a depth of 30 feet to the sea.

Q. (By Mr. Williams.) What was that depth?

A. To obtain a depth of 30 feet. The other route followed the St. Lawrence to Lake St. Francis, and then across country to the lower end of Lake Champlain, thence via Whitehall and Ft. Edward; thence down the Hudson to the junction of the route first described.

Q. (By Mr. Wilkerson.) I direct your attention particularly to the subject of hydraulic measurements on the Great Lakes and on the inter-lake outflow of rivers, and I ask you what connection, if any, you have had with that matter?

A. The board of engineers had measurements taken of the outflow of Lake Erie and Lake Ontario, and through the United States engineer's office in Detroit the outflow from Lake Huron. This constitutes about all the work of that kind that I have been connected with.

Q. Now, over how long a period has your study and your

work in connection with the matters about which you have been testifying extended?

A. Well, I first became interested, particularly interested in lake and navigation matters in 1870 and my work at St. Mary's Falls Canal was directly connected with that until 1882.

Q. Would you say your study and work in connection with those matters has been fairly continuous since that time—that is, kept you in touch with the subject since the time that your connection first commenced?

A. Yes, sir; that is the case.

Q. You say that is the case?

A. Yes, sir.

Q. In connection with your profession are you a member of any association or society?

A. I am a member of the American Society of Civil Engineers.

Q. And have you held any position?

A. I have been president.

Q. During what period?

A. During the year 1903.

Q. Did you have any occasion in connection with that association to make any study of any question connected with the Great Lakes?

A. The president of that society has to present an address to the society about the middle of his term of office, and my subject was the Commercial Development of the Great Lakes —in the main historical.

Q. Of what college are you a graduate?

A. University of Michigan.

Q. And you hold your degrees from the institution, I suppose?

A. Yes, I obtained the degree of Civil Engineer when I was graduated and had the honorary degree of LL. D. since that time.

Q. Basing your answer on your experience and on your knowledge of matters connected with the Great Lakes and navigation, and assuming that a certain definite quantity of water as, for example, 4,000 cubic feet per second is diverted from Lake Michigan at Chicago, I ask you to state what, in your opinion, would be the effect of that as to the lowering of Lake Michigan?

A. I think it would lower Lake Michigan.

Q. Assuming that there was a definite lowering at a point

in Lake Michigan as, for example, 10 miles from Chicago, I ask you to state what, in your opinion, would be the relation of that lowering to the lowering which would take place in other bays and harbors of Lake Michigan and Huron for the whole area of each lake and at the head of St. Clair River?

A. I think there would be the same amount of lowering that occurred at the point 10 miles distant from Chicago.

Q. I ask you to state why you make that answer?

A. The stage of the lake—other things being equal, the stage of the lake is determined by its outflow and by the area of its outlet channels, and if a certain amount of water is diverted in a new channel the lake would fall until a normal discharge through the former channel is reduced by the amount diverted.

Q. What do you mean by the word lower used in that connection?

A. Lower than it would have been without the new diversion.

Q. Do I understand you to mean that as you use the term lowering would take place even though the lake may be actually higher than it was before the diversion of the water took place?

A. Yes.

Q. That is to say, you speak of lowering not with reference to a fixed mark, but with respect to the level that the lake would have in the absence of the diversion?

A. Yes, sir, precisely.

Q. I ask you to state whether or not, in your opinion, it is possible to divert a given amount of water from Lake Michigan at Chicago as, for example, 4,000 cubic feet per second, if the outflow of the St. Clair River goes on permanently undiminished precisely the same as before the diversion was begun?

A. The surface would be lower until the outflow from Lake Huron was less by 4,000 feet than the outflow would have been if the diversion had not been made.

Q. That is to say, I understand you mean that when the lowering effect of the diversion is accomplished the outflow in the St. Clair River would be 4,000 cubic feet per second less for exactly the same conditions of net supply than it was before?

A. Yes.

Q. What do you mean by the term net supply as used in this connection?

A. The amount of water to be disposed of by outflow; the inflow, less the evaporation and absorption—that would be the same.

Q. Can you make that explanation of the term net supply any fuller by the use of an example or illustration?

A. Well, the gross supply is the amount of water coming into the lake, that is the amount flowing in from the surrounding country plus the amount falling on its surface. Those are the main features at least, and a portion of that escapes from the lake by evaporation, and the remainder would pass through the lake by discharging at its outlet, and the remaining portion which is ultimately discharged from its outlet would be equivalent, I should say, to its net supply.

Q. What effect, if any, would the diversion of the water—

A. May I extend that answer, I don't know that this—that the amount discharged is equivalent to the net supply during any given period, though it ultimately becomes that.

Q. What effect, if any, would the diversion of the water from Lake Michigan at Chicago have upon the rainfall, evaporation, absorption, running off from the drainage basin of the lakes or inflow of St. Mary's River?

A. They are all independent of that. Temporarily with the outlet so formed the outflow would be more than under normal conditions.

Q. Treating the diversion of water at Chicago as another outlet like the St. Clair River, and assuming that the net supply is unchanged by the diversion of the water at Chicago, what do you say as to the effect of the diversion at Chicago upon the outflow of the St. Clair River?

A. The outflow of the St. Clair River would be reduced by the amount of the diversion.

Q. What is the effect of the reduction of that outflow upon the level of the lake?

A. I think the situation is reversed. The lowering of the lake reduces the outflow. A diversion of water through an additional outlet would cause a lowering of the lake until the total amount discharged through both outlets becomes the same as would have been discharged from a higher or normal level through the original outlet, and the amount of discharge through the St. Clair River, other things remaining unchanged, dependent upon the stage of the lake, the outflow to the St. Clair would be reduced in the case supposed.

Q. And how long will the lowering go on?

A. Until—it will go on until that condition is reached in

which the discharge of the St. Clair River is less than normal discharge—less than the discharge would have been without the diversion by the amount diverted.

Q. I show you, Mr. Noble, a chart or plat of the river, which I ask now to have the commissioner mark Exhibit 1 of this date, for identification, and I ask you to assume for the purpose of your answer that the observations which are there platted are correct. The discharge measurements therein referred to being platted with Lake height as ordinates and the volume as discharged as Abscissa. This chart shows a diagonal line threading the circles representing these observations drawn to represent or express the law of relation between lake height and volume of discharge. I ask you to examine the plate and state whether or not, in your opinion, that diagonal line drawn to express that law is accurately drawn or correctly drawn (showing)?

A. It seems to me to be accurately drawn.

Mr. Williams: Do I understand now that the answer is for the purpose of indicating the correctness of the plate as an abstract proposition to show the law?

Mr. Wilkerson: I think my question is plain. We are assuming—I am asking the witness to assume the correctness of the observations.

Mr. Reid: That is, lake measurements.

Mr. Wilkerson: On the plate are platted the lake height and the volume of discharge. The line which is drawn through these observations is a line to represent the law of relation between lake height and volume of discharge, and I am asking him for his best opinion as to whether or not that line is correctly drawn.

Witness: It appears to me to be correctly drawn.

Q. Now, assuming, always for the purpose of your answer, the correctness of these observations, I ask you to state whether or not, in your opinion, the line as there drawn expresses correctly the law of relation between lake height and the volume of discharge?

A. I think it does.

Q. I direct your attention to the fact that some of those observations are represented as squares while others are represented as circles. Would you say substantially the same if you were to exclude the observations put down as squares, those being the observations for 1908?

A. That would make very little difference in the position of the true line.

Q. I put to you the same question, the difference being that in the answer the observations which are platted as triangles as included would that make any substantial difference?

A. It would make no substantial difference.

Q. It appears, I think, from the plate that the parts platted as triangles are for 1901?

A. Yes.

Q. I will ask you to take the line embracing the law of relation between lake level and outflow, and assuming the correctness of the observations upon which that law was based, I ask you whether you can give to us a formula or equation which expresses the relation between outflow through the St. Clair River and lake level; that is to say, I want you to explain how you would determine the change in the lake height for a given change in outflow?

A. I would determine from the diagram the change in outflow to the change of height in the lake of one foot, which could be done intimately on the chart, divide by it the suggested change in the outflow and it would give the corresponding change in elevation of lake surface.

Q. Can you state a formula which could be used as the basis for that determination? If so, how would you express it, explaining the terms which you use in the formula?

A. If by Q we designate the outflow of the lake with the surface of the lake at elevation H, and by Δ Q the increase or decrease of outflow, for an increase or decrease in height of lake surface of Δ H, and by I the increase or decrease of outflow for an increase or decrease of one foot in lake elevation, then Δ H equals Δ Q divided by I.

Q. Can you make a statement of that formula or law, Mr. Noble, in less technical language assuming that you were explaining the ultimate effect on the lake level in terms of volume of diversion and the increment: by increment I mean the change corresponding to the foot's change in lake level?

A. The diagram or chart shows or states that the change of outflow corresponding to a change of elevation of lake of one foot as 23,820 cubic feet per second, and by measuring this on the chart—I assume that that is substantially correct—the change of height of lake corresponding to any assumed change in discharge is given by dividing the amount of the assumed change by 23,820.

Q. Will the result be expressed in fractions of an inch?

A. That would be expressed in fractions of a foot. It would be expressed in feet rather than in inches.

Q. Directing your attention again to the plate, Exhibit No. 1 of this date for identification, calling your attention particularly to the portion thereof headed "Scale showing loss of level in Lake Huron corresponding to the loss of outflow on St. Clair River by reason of the diversion at Chicago," assuming for the purpose of your answer, the correctness substantially of these observations and basing your answer upon this law expressed by the diagonal lines as they are drawn, what do you say as to the correctness of that scale; the scale that I refer to is the one at the left hand of the plate?

A. That scale shows the resulting changes in height correctly.

Q. Still having in mind this law or formula of expressing the ultimate effect on lake level of the diversion, what is the lowering of Lakes Michigan and Huron in inches for 10,000 cubic feet diversion?

A. About five inches.

Q. Now, you have given the answer with reference to the diversion of 10,000 cubic feet per second in Chicago, is that true proportionately for the diversion of smaller quantities than 10,000 cubic feet?

A. It is.

Q. That is to say, what would be the lowering for the diversion of 5,000 cubic feet?

A. Five thousand would be one-half of five inches or two and one-half inches.

Q. And 4,000?

A. Two inches.

Q. Can you explain that a little further, Mr. Noble?

A. The lowering of lake level due to the diversion of 10,000 cubic feet per second would be about 10/25 of a foot.

Q. (By Mr. Williams.) That is assuming that a diversion of 23,000 and some odd figures there causes a fall of a foot?

A. Yes.

Q. That is, you always assume that to start with?

A. Yes. Assuming the correctness of this chart the fall for the diversion of 4,000 cubic feet per second would be about 4/24 of a foot.

Q. Between 4/23 and 4/24?

A. Yes.

Q. (By Mr. Wilkerson.) If a certain quantity of water is

diverted at Chicago through the drainage canal what will be the effect ultimately upon the outflow of the Niagara and St. Lawrence Rivers?

A. It would be the same reduction in outflow.

Q. What would be the effect on the Erie?

A. Lake Erie would fall until its discharge was less by the Chicago diversion than the discharge that would have occurred without that diversion.

Q. What would the effect be on Lake Ontario?

A. The same.

Q. What, in your opinion, would be the effect upon the St. Clair River, Lake St. Clair, Detroit River, Niagara River, St. Lawrence River and St. Mary's River?

A. They would all be lowered; the St. Mary's River below the falls.

Q. I show you, Mr. Noble, plates which I ask to have marked Exhibits Nos. 2, 3 and 4, respectively, for identification of this date—assuming for the purpose of your answer the substantial correctness of the observations platted, I ask you to explain to us as an engineer what those plates represent and to give us a statement as to the correctness of the law or formula as represented by the diagonal lines on each one of the plates, and, if you will in explanation of the plates, I will ask you to make your answer rather complete so that we will have translated in a less technical way the meaning of those plates?

A. I have examined the three charts referred to and in my judgment the lines representing the relation between the height of the water surface and discharge is substantially correct.

Q. Directing your attention to the scales at the left hand side of each of those plates, I will ask you to make the same examination that you made with reference to the scale on Government Exhibit No. 1 for identification and to state what is the fact with reference to their correctness?

A. They are substantially correct.

Q. That answer applies to each one of the plates, does it, Mr. Noble?

A. Yes.

Q. Giving to the letter Q and H and Δ Q and Δ H, the same significance that was given to them in the plate Government Exhibit No. 1 for identification, I ask you to examine the formulæ which appear on each one of those plates and state the fact as to the correctness or incorrectness of that formu-

læ as expressed in the changed relations represented by each of the plates.

A. The formulæ express the relation between the change of height and the change of discharge correctly, assuming the correctness of the lines—the diagonal lines—on the several charts.

A. And I understand you to say that assuming in each case the correctness of the law representing these changed relations as indicated by this diagonal line you find the scales on the left hand side of each of the plates correct as representing those changes in inches?

A. They are.

Q. I also understand you to give it as your view that the lines are substantially correct, assuming the correctness of the observations?

A. Yes; the correctness of the observations and the platting thereof.

Q. So that if the observations were correctly made and are correctly platted on each one of these Exhibits Nos. 1 to 4, respectively, the scales at the left hand side of each of those plates are correct?

A. Substantially correct.

Hearing adjourned until Tuesday, February 16, 1909, at 10 o'clock a. m., at 315 Fifth avenue.

New York, February 16, 1909.

Present:

The Commissioner and counsel as before.

Hearing resumed at No. 315 Fifth avenue, New York, pursuant to adjournment.

ALFRED NOBLE, recalled:

Direct Examination Continued by Mr. Wilkerson.

Q. Directing your attention again, Mr. Noble, to the relation between discharge and height of lake, I want to ask you this question: Assuming that running over a number of years you have a series of measurements representing the discharge and height of lake, could you give a method of reaching a formula which would express the relation between those two?

A. The first part of the method would be to plat the observations on paper ruled at right angles so that horizontal lines,

for example, would represent stages of the lake, and the vertical lines represent discharges; and a line can be drawn by the eye, which is probably the way in which I would do it with my limited knowledge of the art, which would represent as fairly as I could make it an average of these observations. That is sometimes done by more accurate methods, with which I am not thoroughly familiar.

Q. Having drawn that line, then what would be the next step?

A. Then you could read from that diagonal line the relation between the stage of the lake and the discharge.

Q. Just what would that line represent?

A. Represents the relation between those two factors.

Q. Directing your attention again to Government Exhibits Nos. 1, 2, 3 and 4, I ask you what you have to say of those with reference to the method of determining this relation between lake height and discharge; in other words, what have you to say as to those charts as representing a method of reaching a conclusion on that subject?

A. The diagonal lines on those charts seem to me to represent fairly that relation between height of lake and discharge.

Q. And are those lines drawn in accordance with the methods which you have indicated as you would do if you had the series of observations?

A. I don't know that. They are substantially the lines I would draw if I were to draw lines representing that relation. They would not differ substantially.

Q. I am, of course, assuming the correctness of the observations and assuming that they are correctly platted as we did yesterday.

A. Yes; I am also assuming that.

Q. Assuming that the observations are substantially correct and that they are correctly platted, in order to get an expression of that relation the method you would follow is the one that has been followed in the preparation of those charts?

A. I don't know as to that.

Q. I mean drawing the lines.

A. Drawing a diagonal line on some basis or other is what I should do. But I should probably draw the line by eye and I should draw it with the limited range of observations and the limited range of lake levels represented by these observations and draw it as a straight line, and its position would not differ materially from the position shown on the charts or chart.

Q. What experience have you had in connection with the measurements of Lake Erie on this matter of height of the lake and discharge?

A. Gaugings were made of the outflow of Lake Erie and the upper end of the Niagara River under the general direction of the United States Board of Engineers on deep waterways, of which I was a member. The work was carried out by Mr. E. E. Haskell, who was engineer in charge, with Mr. Shenehon and Mr. Stewart as assistants in the various parts of the work.

Q. What was the result of that work? Tell us all about it as far as you know.

A. Measurements were made under the direction of that board—were taken from the International Bridge at Buffalo, and measurements were made by the Haskell current meter.

Q. What was the increment as the result of that work?

A. The curve drawn to represent the result of those gaugings—the line drawn to represent the relation between stage of lake and discharge was drawn as a curve, having a slight curvature, and from different portions of the curve the relation between height of lake and discharge varies slightly—increment I should say varies slightly; the varyings in the two portions of the curve which I measured were from 22,000 cubic feet per second for a change of elevation of one foot to 24,800 feet a second.

Q. What period did the observations on which that computation is based cover?

A. I could not answer that without referring to the records. It might have continued some months as I recall it.

Q. Do you know anything about lake observations having been made there and if so what would be the effect of those lake observations on the precision of drawing the degree of accuracy which you could make a statement as to?

A. In the reports of the chief engineers are given statements in regard to the subsequent gaugings, the important ones being taken 2,000 and 3,000 feet below the International Bridge, and the relation between height of lake and discharge is substantially the same as in the first series of observations.

Q. Referring again to the diversion of water from Lake Michigan at Chicago, what would be the effect of that diversion upon the available power of the Niagara River?

Mr. Williams: We have reserved in the stipulation objections as to that.

Mr. Wilkerson: As to the competency, materiality and relevancy of the testimony.

A. The effect would be to reduce the amount of water power available.

Q. And with reference to the St. Lawrence River?

A. The same result in kind.

Q. Have you given consideration, Mr. Noble, to the matter of data regarding the evaporation and the use of data of that kind in any attempt to detect presence or absence of the effect produced at the lakes by the diversion of the water made at Chicago?

A. It doesn't seem to me useful and it seems to me to be entirely unnecessary.

Q. Will you state the grounds upon which you base that answer?

A. The withdrawal of water through a new channel is the only new condition introduced in the case. Suppose we have only to deal with the results of the new condition, the evaporation, the inflow are not in any wise changed.

Q. What is your general information on the subject of the accuracy of data with reference to rainfall and evaporation—the degree of accuracy?

A. I do not understand that rainfall observations have been made, or evaporation observations in detail over the whole Great Lakes territory, and I should think a large percentage of doubt would exist in any figures that might be used in that connection.

Q. In your opinion are the figures relating to rainfall and evaporation sufficiently accurate so that they may be used as an element in reaching any correct conclusion on the subject whatever?

A. I should think they are not definite enough or accurate enough for use, and if they were definite and accurate they would be absolutely unnecessary I think for the purpose of determining the changes of elevation of the lake due to the diversion of water through new channels.

Q. You are familiar, I think you said yesterday, with the hydraulic measurements which have been made in the St. Clair River. I wish you would give us your judgment as to the scale on which these measurements were made and as to the competency of the persons who directed the making of those measurements.

A. I think those measurements were very carefully done by people who are exceedingly competent to make them.

Q. Do you know who made them?

A. I think the first St. Clair measurements, if I remember rightly, were made by Mr. Sabin, either by Mr. Sabin or Mr. Shenehon. My recollection is that they were made by Mr. Sabin.

Q. What do you say with reference to the skill with which the measurements of the Niagara River were made and the competency of the person under whose direction those measurements were made?

A. I think they were made with skill and by competent persons.

Q. By men qualified to do the work and giving as accurate results as could be obtained under the circumstances?

A. I believe so.

Q. What do you say about the measurements of the St. Lawrence River?

A. The same.

Q. And the St. Mary's River?

A. The same.

Q. Have you any opinion as to the degree of precision with which this line representing relation between stage of the lake and discharge has been drawn—I refer to the percentage of accuracy?

A. I should think that the lines drawn would represent the results of the observations as platted within about 1 or 2 per cent. and within the range of the observations themselves.

Q. What is your judgment as to whether or not the lowering of the lake level, as you have used that term, about from two to three inches is a material or substantial modification of the navigable condition of the lake?

A. I should expect the reduction of that amount to really effect the loads that ships could carry.

Q. In a substantial way?

A. I think in a substantial way, yes.

Q. Explain that if you will?

A. Well, in a rough way and as an approximation, the loads one of the largest class of lake freighters would carry would be reduced about 60 tons by the inch reduction in draught.

Q. You determine tons by what pounds?

A. Twenty-two hundred and forty pounds to the ton.

Q. Have you any knowledge on the subject of the expense of operating vessels of different draughts, whether if you in-

crease the draught of the vessels two or three inches it would cost very much more to operate it or not?

A. I don't see how it could effect the cost of moving a ship a mile, for example, but I have never figured it out with any degree of precision.

Recess until 2 o'clock p. m.

After recess:

ALFRED NOBLE, recalled:

Cross-Examination by Mr. Williams.

Q. Mr. Noble, assume a diversion of water at Chicago sufficient to lower the level of Lake Michigan one foot, what in your opinion would be the effect, if any, on the depth of water in the Gulf of St. Lawrence?

A. I couldn't say; it would be a very small allowance.

Q. In your opinion would there be any proportionate effect.

A. No; I should think not. Not appreciable by any ordinary methods.

Q. Assuming the same state of facts in a diversion sufficient to lower the level of Lake Michigan one foot at Chicago, what would be the effect, if any, on the depth of water in Lake Superior?

A. I don't think that it would be appreciable. I don't see how that could affect Lake Superior.

Q. What would be the effect on the depth of water in Lake Huron?

A. I think it would be a foot.

Q. Practically the same effect as on Lake Michigan itself?

A. The same effect as on Lake Michigan itself.

Q. What would be the effect in your opinion on the depth of water in Lake St. Clair?

A. I don't know. I haven't studied that matter and I don't know.

Q. Would it be more or less in your opinion?

A. I have no opinion on that point.

Q. You have no opinion then as to whether or not the effect on Lake St. Clair would be greater or less than on Lake Huron?

A. No; I couldn't say from my own studies and reading.

Q. Have you an opinion, and if so what is it, as to the effect on the depth of water in Lake Erie under such conditions as I have mentioned as compared with the effect on Lake Michigan?

Mr. Reid: You are now talking about a foot diversion?

Mr. Williams: Yes.

A. I should have to think that over; I couldn't answer it offhand.

Q. Would you be able to state without very much figuring whether the effect would be more or less in Lake Erie, for instance, than it would be in Lake St. Clair—the effect of the diversion at Chicago I am speaking of?

A. I think that question ought to be readily answered if one had time to look over the data and do the necessary figuring, but I couldn't tell it now.

Q. Would you be able to state whether or not the effect of such a diversion at Chicago would be more noticeable, more or less noticeable in Lake Ontario than in Lake Erie—by the word noticeable I mean would it affect the depth of Lake Ontario more or less than it would Lake Erie?

A. I think I shall have to make the same answer as before. That answer does not seem to be a difficult one to give if one could look over the figures with a view of ascertaining that, but I have not.

Q. I am not asking for figures.

A. I know, but still it involves the same sort of consideration.

Q. In your opinion would a diversion of water from Lake Michigan at Chicago sufficient in extent to cause the lowering of the levels of Lakes Michigan and Huron to the extent of one foot be likely to lower the level of any of the Great Lakes, or the rivers connecting the lakes to an extent greater than one foot?

A. I would not want to answer that offhand.

Q. I will ask you whether or not you have an opinion, and if so, what it is, as to the effect of the diversion of water at Chicago sufficient to lower the level of Lake Michigan one foot on the depth of water in the St. Clair River?

A. That involves the same sort of consideration as the other questions.

Q. And you would give the same answer?

A. The same answer, yes.

Q. And would you answer in a similar manner the same

question with reference to the Detroit, Niagara and St. Lawrence Rivers?

A. Yes.

Q. Suppose there were a diversion of water from Lake Superior sufficient to lower that lake one foot, what in your opinion would be the relative effect on the level of Lake Huron?

A. If applied instantaneously, the effect would be the raising of Lakes Huron and Michigan, which I assume to take place simultaneously, being proportioned to the sum of the areas of those two lakes to Lake Superior.

Q. The diversion assumed is not a diversion of Lake Superior into Lake Huron, but a diversion of water from Lake Superior; suppose it were of a nature similar to the diversion which has been spoken of here at Chicago?

A. I should think the effect of reducing the inflow into Lakes Huron and Michigan would be, so far as I see, equivalent to like a withdrawal through another channel from Lakes Michigan and Huron.

Q. If the diversion was sufficient to lower the level of Lake Superior one foot, can you give us an opinion as to how much that would lower the level of Huron?

A. That involves so much more data than I have that I couldn't answer that.

Q. Would that effect be contingent upon the discharge of the two lakes in any way; that is, if you knew the distance of Lake Superior and the discharge of Lake Huron, would that assist any in forming an opinion as to the relative effect of the diversion of this water from Lake Superior?

A. That would be pertinent to a study of the subject certainly, but I hesitate to say; I don't want to give an answer offhand. The effect of those changes takes a little time.

Q. I assume that this is a permanent diversion and I am speaking of the effect after the equilibrium has been established.

A. That would have a variable effect upon the Lake Huron. It would reduce the amount of water flowing into the lake by an amount of the diversion, and it would not be a constant and invariable reduction of the level of Lake Huron in amount; there would always be something and the variations would be constantly equalized by the lake storage feature.

Q. In your opinion would the level of Lake Huron be lowered more or less than a foot?

A. I think that matter is pretty closely determinable with a little study. While I have an impression on the subject I can hardly say it is an opinion. It is an impression which might be absolutely changed by an examination of the matter, that the effect on Lake Huron would be less than on Lake Superior. I am not very sure of that.

Q. And would the discharge of Lake Superior in proportion to the discharge through the St. Clair River bear any relation to the proportion between the lowering of the level of the two lakes—whether there is any relation at all between them?

A. A change in elevation of a foot in Lake Superior would correspond to some condition variable, depending upon the stage of the lake and still some positive difference in discharge from Lake Superior, no matter how that lowering of the surface was obtained. If that were a permanent one, or practically a permanent one, its effect on Lake Huron would be determined by the corresponding increment and discharge from Lake Huron, that is the effect such an increment or change in inflow would have upon the outflow, the increment of outflow being the same, I should say, as the increment of inflow, the amount of the change in the outflow being the same with the change in inflow that the effect upon the stage of Lake Huron would be quite determinable from the discharge curve.

Q. Suppose, Mr. Noble, that there were a permanent diversion of 20,000 cubic feet per second from Lake Superior, what would be the relative effect upon the levels of Lake Superior and Lake Huron in the case of such a diversion?

A. I don't know. I couldn't tell without referring to the data what the effect on the level of Lake Superior would be. It would fall until its outflow was 20,000 feet less than the normal outflow.

Q. Without reference to how much it would affect the level of the lake—

A. That is not a necessary feature—

Q. Can you indicate what the effect would be as compared with the effect on Lake Huron?

A. What effect the reduction of 20,000 feet in the inflow would have on the outflow?

Q. On the elevation?

A. I think that could be read so far as I see from the discharge curve. I think that would be the only disturbing element brought into the situation.

Q. Now, assume, Mr. Noble, that the discharge from St. Mary's River is 77,000 cubic feet per second and that the discharge from the St. Clair River is 197,000 cubic feet per second, would the withdrawal and diversion of 20,000 cubic feet per second have a greater or less effect upon the level of Lake Superior than it would have upon the level of Lake Huron?

A. That question ought to be easily answered with the data, but I haven't them before me.

Q. Have you given some attention, Mr. Noble, to the effect of the regulation of Lake Erie in connection with the developments of navigation?

A. That matter was taken up by the United States Board of Engineers on Deep Waterways.

Q. Of which you were a member?

A. Of which I was a member, yes.

Q. Do you recall from the investigation that you made at that time what the effect of such regulating works would be on Lake St. Clair as compared with Lake Erie?

A. My recollection—although I did not make those figures in detail—my recollection of the conclusions of the board are that about—that a change of three feet in Lake Erie would produce a change of two feet in Lake St. Clair and about one foot in Lake Huron. That is a matter of recollection.

Q. I think your recollection is very good. That was your opinion and is still your opinion as to the effect of those works?

A. Well, that is, I haven't gone into the matter since. I haven't used any of the new data which I believe exists in that connection. That was rather a rough approximation that we considered at the time.

Q. You have not, however—

A. I haven't gone into the matter since and have used none of the data collected since.

Q. So that you have not changed your opinion?

A. I should think there were better data existing.

Q. Yes; but you have not availed yourself of that data so as to change your opinion yet?

A. So far as the opinion went I think that is right.

Q. The contemplated plan suggested by your board at that time involved the raising of the level of Lake Erie 2.14 feet, did it not?

A. I don't remember that.

Q. Do you recall what the cost of the regulation was as estimated by your board, approximately?

A. I would like to have that understood that it is merely a rough estimate; I think it was eight or nine hundred thousand dollars.

Q. I will ask you in this way—

A. I can verify that very readily.

Q. I can ask you whether it was not $796,923?

A. I think that is it. It is not very far from that amount according to my recollections and I assume that it is correct.

Q. Suppose, Mr. Noble, that the outlet of any lake were restricted by an obstruction, that would result in the surface of the lake rising, would it not?

A. I think so.

Q. And then after the equilibrium had been established, the obstruction having remained there a sufficient length of time for that purpose, if the obstruction were removed the surface of the lake would then return to its original elevation, or level, would it not?

A. In time, yes; return to the elevation it would have had if the obstruction had never been introduced.

Q. Now, you testified this morning with reference to the effect of the lowering of Lake Michigan by a diversion of 4,000 cubic feet per second at Chicago.

A. Yes.

Q. Is that the basis of your testimony this morning, or was it an assumed condition of the lowering of two inches, do you recall?

A. That was yesterday. The question was in relation to the effect on Lakes Michigan and Huron of withdrawing 4,000 feet from Lake Michigan.

Q. And you testified that the effect would be about two inches?

A. About two inches.

Q. And then following that up you testified as to the effect on navigation in Lake Michigan?

A. I think some question was asked me about that subject this morning.

Q. Now, then, on what parts of Lake Michigan would navigation be affected by a diversion of 4,000 cubic feet per second?

A. It would be only in those harbors where the depth of water was near—it would apply only to those harbors where

the limit in depth corresponded closely with those on the route traversed by any given ship.

Q. Are you able to testify as to what harbors come within the purview of your last answer?

A. No, I couldn't. I don't know what the conditions are.

Q. Do you know of any harbor on Lake Michigan where navigation would be interfered with by the diversion of 4,000 cubic feet per second?

A. I am not informed as to the depth of water in any harbor on Lake Michigan.

Q. I will ask you the same question with reference to Lake Huron. Do you know of any harbor on Lake Huron that would be so affected by the diversion of 4,000 cubic feet per second at Chicago as to substantially interfere with navigation?

A. I don't recall any. I don't know the depth of harbors in Lake Huron.

Q. Without repeating the question I will ask you whether or not you can enumerate what portion, if any, of the St. Clair River would be affected and to what extent, and to a sufficient extent to substantially interfere with navigation?

A. I don't know that. I don't know of any critical point in the St. Clair River.

Q. How about the Detroit River?

A. I should suppose that at some points in the neighborhood of the Lime Kiln Crossing and Ballard's Reef might be the case in point as affecting the large commerce.

Q. Now assuming this withdrawal of 4,000 cubic feet per second in Chicago from Lake Michigan, have you an opinion as to the extent of the lowering of the level of the Detroit River by such a diversion?

A. I don't know the exact amount. That involves the same consideration as the series of questions you asked a short time ago. It is determinable, but I haven't the data before me now.

Q. Is it necessary to determine that in determining whether or not navigation will be substantially interfered with in the Detroit River?

A. That would be easily determinable relation, I should say, between the depth of water in Lake Michigan, or between the elevation of the surface of Lake Michigan and the reduction of depth at the critical point. There would always be, so far as I can see, the reduction in elevation due to the 4,000 feet less supply to the river.

Q. But until you have had the data submitted to you and you have calculated the extent of the lowering of the Detroit River you would not be able to express an opinion on the extent of the interference with navigation by that division?

A. I think it would go a little farther than I had in mind when I answered your question before. The effect on the only portion of the Detroit River that would be important in this case would follow very closely the effect upon Lake Erie, which is determinable and readily so.

Q. You have spoken of a point on the Detroit River in the vicinity of the Lime Kiln Crossing?

A. Yes.

Q. Can you state the extent of the river in miles that would be so affected?

A. I haven't that in mind.

Q. Approximately; I don't mean accurately?

A. No, I don't know that. I don't know what length of river would be affected; that would involve the question as in what part of the present channel the water is least I should say; but the effect on lowering the level, I think, could be readily determinable throughout this entire stretch mentioned within a small margin, and within that small margin I think it would be the same as that in Lake Erie.

Q. Now the, coming to Lake Erie, you may, if you will, state what harbors in Lake Erie will be so affected by a withdrawal of 4,000 cubic feet per second of water from Lake Michigan at Chicago so as to substantially interfere with navigation?

A. If that question is as to the entrance of vessels into the harbors in question I would say at once I don't know; but I think that the withdrawal or lowering of water in Lake Erie will affect all of the important navigation on Lake Erie by reason of affecting the water in connecting channels; the Detroit River, possibly the St. Clair River and pretty certainly the St. Mary's River.

Q. I understood you to say that you were not able to give any opinion with reference to any portion of the St. Clair River.

A. I am not certain about the St. Clair River. I do not recall any place there that limits the draught of vessels.

Q. The navigation on the Niagara River; would that in your opinion be substantially interfered with by the diversion of the 4,000 cubic feet per second at Chicago?

A. I can't say as to that, because I am not familiar with the depths of water in the Niagara River, but if my recollection is correct, that there is shoal water that limits them there, I should say the surface of the river would certainly be depressed by such a withdrawal from Chicago. It would be at the head of the river substantially that given by the discharge curve in question in Lake Erie, and as to whether it would be more or less coming down the river I wouldn't undertake to say.

Q. Are you familiar with the kind and size of the craft that navigate the Niagara River?

A. Not particularly.

Q. Is it not true as a general statement that it is only navigated by small craft at present, that is, that large lake vessels do not use the Niagara River for navigation purposes?

A. I am not positive as to the facts in this case.

Q. Now I assume that with reference to Lakes Michigan, Huron, Erie and Ontario, your answer would be the same, that the only portions of those lakes in which navigation would be substantially interfered with by a diversion of 4,000 cubic feet per second in Chicago would be the harbors?

A. And the connecting channels.

Q. We took this up separately. We have mentioned each one of the connecting channels.

A. Address that question again.

Q. Is there any portion of Lake Michigan, Lake Huron, Lake Erie or Lake Ontario, except the harbors and the connecting channels where navigation would be seriously or substantially interfered with by the diversion of 4,000 cubic feet per second at Chicago?

A. I think there is ample depth for navigation.

Q. Are you able from your own knowledge to state or give the name of any harbor on Lake Ontario where navigation would be substantially interfered with by the diversion mentioned at Chicago?

A. I don't know; I am not familiar with the harbors in Lake Ontario.

Q. In your opinion would navigation on the St. Lawrence River be substantially interfered with by the diversion of 4,000 cubic feet per second at Chicago?

A. The interference, by which I mean the reduction of depth for navigation over the shoal places would be affected by the withdrawal of water from Lake Michigan at Chicago.

Q. What I wish to know is if you are personally familiar

with the shoal places so that you can tell us where, if at all, on the St. Lawrence River channels would be affected?

A. I don't think I am familiar enough with the navigation of the St. Lawrence River to answer that question.

Q. This morning I understood you to say that there would be a loss by decrease of loading in vessels amounting to about 60 tons to an inch?

A. Yes.

Q. What depth or draught boat did you have in mind in making that estimate?

A. The type of boat I had in mind was one about 550 feet long and 56 foot beam, which is not the largest but one of the larger class of boats now engaged on the lakes, and the amount of the loss would not vary much; there would be quite a little change in draught.

Q. What would be the total tonnage of such a vessel?

A. The total loading, as near as I remember, would be in the neighborhood of 10,000 tons.

Q. How many feet of water would such a boat draw; what is the depth of the draught?

A. I think in the neighborhood of twenty.

Q. Twenty feet?

A. I think so.

Q. Twenty feet is 240 inches?

A. Yes.

Q. Sixty tons to the inch?

A. No; not for 240 inches.

Q. How many inches?

A. Because the boat doesn't sail along through the air when it has no load; it still draws water.

Q. How many inches?

A. I don't know that precisely. That is a very obvious consideration; I did not determine this in that way and I don't recall now what the average draught of those larger boats is like.

Q. Do you know about how many vessels there are now navigating the Great Lakes of the capacity and tonnage that you had in mind?

A. No, I don't recall; not a great many.

Q. Not a great many?

A. Not a great many, no.

Q. Suppose the water was lowered a foot instead of two inches, would that reduce the loading by the same amount?

A. Practically so. By the same relative amount, you mean?

Q. Yes.

A. Yes.

Q. You mean by relatively that it would be six times as much as two inches?

A. That is it exactly.

Q. Without reference to the loss of tonnage, 60 tons to an inch, would the loss of a foot of water, or reduction of the depth of water by one foot reduce the depth of the loading by the same amount, that is, a foot?

A. I think so. My immediate connection with those matters is, of course, pretty old, but during the time that I was directly connected with the work the skippers watched the stage very closely and took the load for every inch of water there was over the shoal places, and my information is that that is still the case.

Q. Is it or is it not true that the difference in elevation between Lakes Huron and Erie has been 9/10 of a foot less since 1886 than it was before that time?

A. It is my recollection of the situation at the time the report was written that for substantially the period mentioned the records of the stages of the lake seem to show that difference.

Q. Now then, do you know or are you able to give an opinion as to what causes contributed to that difference?

A. It is my recollection of the situation at the time speaking under the reservation of trying to recall a matter that is several years old, I believe that we—I think that we were led to believe by a comparison of the survey made before 1870 with the one made I think after the deep waterways board began its work, there is indicated an enlargement of the outlet to Lake Huron from which it was believed and I think Mr. Wisner made some calculations to show that, such enlargement would result in about the difference of level stated. I think the inference that the enlargement occurred about 1886 was based entirely upon the records of the stages of the lakes.

Q. Have we got in the record now an opinion by you as to whether or not there was such a condition to start with?

A. I don't know. My recollection is that another survey was found prior to 1886 which did not agree with the one which we used, and I have never gone into the matter since

to revise my opinion, and the effect of the new data has been to leave me in some doubt as to the old.

Q. You testified this morning, Mr. Noble, with reference to the accuracy of the discharge measurements. I will ask you to state whether or not in your opinion the discharge measurements which are taken by the government engineers and concerning which you were asked this morning are the most accurate that it is possible to procure at this time?

A. I don't know of any better way.

Q. Do you know of any other information which you would compare favorably with these in accuracy on the subject of discharge measurements?

A. That calls for a little more expert knowledge upon the subject than I have. I have read of some difference of opinion by engineers as to the precision and accuracy of meter measurements and float or rod measurements. In an ideal channel I think the rod measurement would give—I don't see why it shouldn't give at least as good results.

Q. Do you know of any other measurements being in existence on the particular channels involved here than these?

A. I think in the St. Clair River there was an old—I think the double float measurements made in the '60s.

Q. The information prior to 1898 is rather incomplete, is it not; prior to 1898 the information at hand with reference to these gaugings is rather indefinite and unsatisfactory, is it not?

A. I don't think the measurements made in the earlier days were made—of course they were not made with the whole knowledge the subject afterward acquired, but my impression is, without having the comparison before me, that the former measurements of the Niagara and St. Clair Rivers were fairly good. I don't remember now how the St. Lawrence River measurements compare, and in arriving at such an opinion my opinion would be the result of the later measurements.

Q. I just want your opinion as to the relative accuracy of the discharge measurements that are referred to in the plats exhibited to you and concerning which you have testified.

A. I would not be able to discriminate between those with the limited expert knowledge I have on the subject; they are all taken by competent engineers and during much the same period.

Q. I did not ask you to compare one sheet with another. Was that the best information so far as you know?

A. In my opinion they are the best information available without knowing exhaustively the rest of the data.

Q. Your estimates of the specific effect of the diversion of water at Chicago are based entirely upon the results of these discharge measurements, this platting produced and presented here by the government and shown as Government Exhibits 1, 2, 3 and 4?

A. Those are all that I used, I think, in estimating.

Q. And your estimates are based upon them?

A. Yes, sir.

Re-direct Examination by Mr. Reid.

Q. In regard to the last question, you have independent knowledge in regard to Lake Erie? You made measurements there independent of any charts or anything else in this case in regard to Lake Erie, did you not?

A. I don't know that I am clear as to whether you include all the discharge measurements in Lake Erie or not.

Q. The Board of Engineers of Deep Waterways made them?

A. Yes.

Q. In regard to Lake Erie?

A. In regard to Lake Erie.

Q. And you stated this morning some figures in regard to Lake Erie?

A. Yes.

Q. Now they had nothing whatever to do with these charts here?

A. I would like to examine those charts with reference to that.

Q. I say in answering the question this morning, the Board of Deep Waterways, they didn't have these charts here?

A. No.

Q. You did not have these charts Government Exhibits 2, 1, 3 and 4 in mind when you gave those figures in regard to Lake Erie?

A. No. Those figures in regard to Lake Erie —

Q. They were independent of any charts in this case?

A. Yes; they were taken from old measurements of the Board of Engineers on Deep Waterways.

Q. In regard to the effect that this diversion at Chicago would have on navigation at certain points on the Great

Lakes, you call them critical points, do you not, of navigation?

A. They can be called so.

Q. I will ask you Sturgeon Bay Canal and Green Bay Entrance and Manitou Passage as well as the mouth of the Detroit River and one end of Lake Erie as it approaches Toledo might be included as critical points and would be affected by a lessening of the height two inches or more?

Mr. Williams: I object to the question on the ground that it is leading and suggestive, and on the ground that the witness has already testified fully as to his personal knowledge of the points at which navigation would be affected.

Question withdrawn.

Q. I wish to refresh your memory in regard to some of these critical points of navigation. Can you think of any more than you stated to Mr. Williams?

A. Points in the St. Mary's River I have in mind.

Q. Any others?

A. I don't know the circumstances in regard to any others. I do not recall at this moment any other points than those in the first two streams; the depths of the harbors I am not familiar with.

Q. In your first answer to Mr. Williams you said the entrances to the harbors would be affected by this two-inch diversion and the shoals of the lake would be affected and that would affect navigation?

A. Where the depth of the water was near the critical depth.

Q. And that would be in regard to the shoals as well as in entrance to the harbors?

A. Yes.

Q. And you gave the figures to Mr. Williams as $796,923 as the amount of the cost to have the regulating works as made by your report of the Board of Engineers of Deep Waterways; now has that been revised to date?

A. Not that I know of; that is the figure given.

Q. Can you give us an estimate of how much more it would cost to complete them now than the estimate at that time?

Mr. Williams: I object to the question on the ground that it assumes that there is an increased cost since that estimate was made.

Q. Is there an increased cost now than there was at the time this estimate was made?

A. In the cost of works in general?

Q. Yes.
A. In my opinion, yes.
Q. Can you give us any amount?
A. No, I wouldn't want to do that without going over the matter in some detail.
Q. You haven't anything in mind now?
A. No, I haven't anything in mind.

Signed and sworn to before me this 8th day of March, 1909.

Hearing adjourned to February 17, 1909. at Ithaca, N. Y.

Ithaca, N. Y., February 17, 1909.

Appearances:

Frank R. Reid, Esq., Assistant United States Attorney, for plaintiff.

John C. Williams, Esq., for defendant.

Prof. EUGENE E. HASKELL, called as a witness on behalf of the plaintiff, being duly sworn, testified as follows:

Direct Examination by Mr. Reid.

Q. What is your name?
A. Eugene E. Haskell.
Q. Where do you live, Mr. Haskell?
A. Here in Ithaca, New York.
Q. What is your profession?
A. Civil engineer.
Q. How long have you been engaged in that profession?
A. Nearly 30 years.
Q. Of what schools are you a graduate?
A. I am a graduate of this college—this college of Civil Engineering—Cornell University.
Q. Do you occupy any official position in the university?
A. I am the director of the college.
Q. And what is the scope of your duties in connection with the college at this time?
A. Largely executive.
Q. How many years have you been connected with this college?
A. Since the fall of 1906.
Q. Where were you before that?
A. Engaged in practical engineering work.

Q. Where? Just generally, now.

A. I was five years on the Mississippi River; eight years with the Coast and Geodetic Survey in Washington, and thirteen years with the Lake Survey.

Q. Now, just give us an idea of what your duties consisted of with those surveys?

A. On the Mississippi River I was engaged in surveys—hydraulic surveys of the river. With the Coast and Geodetic Survey, I spent almost all my time upon the tides and currents of the coast, and the hydraulics of New York harbor, also on Long Island Sound.

Q. Have you held any position with the government—a member of any boards, rather?

A. I am at present an International Waterways Commissioner.

Q. What is that?

A. It is a commission that has to deal with matter pertaining to the Great Lakes, that is of common interest to the United States and Canada.

Q. And what in regard to the Great Lakes?

A. That is, the diversion of water and the preservation of their stages.

Q. What other experience have you had in regard to the Great Lakes?

A. I have been connected with the surveys and with the investigation of lake levels; in fact, I planned the investigation of lake levels that has been going on since 1898.

Q. Just give us, in a general way, with whom you were connected in that work?

A. With the United States Lake Survey, located at Detroit. The work really started before the Lake Survey was organized, in the United States Engineer's office at Detroit.

A. Can you name any of the individuals that assisted in this work?

A. General Leydecker was in charge of the engineer's office at the time the investigation started; he was also later in charge of the Lake Survey. In 1901, the Lake Survey was transferred to—now—Colonel Fisk of the Engineer Corps.

Q. Now, what range did your investigations cover—just a general idea?

A. A general idea?

Q. Yes. What the actual work consisted of.

A. The work consisted of—in the collection of gauge rec-

ords; that is, of the stages of water of the several lakes and of their connecting rivers, and of the measuring of the discharge of the lake outlets.

Q. Now, can you give us a general idea of where those investigations were—

A. On all the lakes and their outlets.

Q. Now, can you give us some of the outlets there?

A. The St. Mary's River is the outlet of Lake Superior; the St. Clair River is the outlet of Lake Huron; the Detroit River is the outlet of Lake St. Clair; the Niagara River is the outlet of Lake Erie and the St. Lawrence River is the outlet of Lake Ontario.

Q. What systems or devices did you use in doing this work; any particular ones?

A. Why, we designed a special self-regulating gauge for the registering of the stages of water.

Q. What is the common name of that? What is that known by; what is the name?

A. The gauge is officially known as the "United States Lake Survey self-registering gauge."

Q. That was used in all your work, was it; in this connection?

A. Well, not all of it. We had to resort in many instances to the use of staff gauges or float gauges.

Q. Now, what other instruments or devices were used in this work?

A. We had sounding machines for making soundings and current meters for measuring velocities.

Q. What were the current meters?

A. We used the meter which I designed, known as the "Haskell Current Meter."

Q. Now, these instruments and devices that you used were the best devices that could be obtained for this work, and these investigations?

A. We considered them so.

Q. Now, from your experience in dealing with the Great Lakes and the levels and the outflow and other work that you have described, have you an opinion as to whether or not the diversion of water at Chicago to the amount of four thousand, five thousand, ten thousand and fourteen thousand cubic feet per second, would in any way affect the navigable capacity of Lake Michigan, or the Great Lakes? First, have you an opinion?

A. Yes.

Q. Now, would it affect the navigable capacity of Lake Michigan or any of the Great Lakes?

Mr. Williams: I object to that.

A. Yes.

Q. Have you, or do you know of any system of measuring the amount of the decrease or effect on the lake level of a certain outflow or diversion of water through a channel, or any other means of diversion?

Mr. Williams: Objected to on the ground that it calls for a conclusion of the witness on a question which is to be determined by the court from the facts, and not from conclusions alone.

A. Yes.

Q. Now, in regard to the word "lowering" as used in connection with the Great Lakes, what do you understand that to mean?

A. A decrease in the stage of water, an actual lowering of the water surface.

Q. Just give us a further definition of what you mean. I am talking now in relation to a diversion of a body of water from a body of water, what would you mean by the lowering?

A. That is a diminishing of the stage. That is, the mean level of the lake for a certain year may be up here (indicating on blue print) and due to the diversion for the next year it might be a certain quantity lower.

Q. Now, might the lake be actually higher and still have a lowering, in the sense that you mean?

A. Yes, sir.

Q. That is what I meant.

A. Yes.

Q. If 4,000 cubic feet per second should be diverted at Chicago would that lower Lake Michigan at a point ten miles off from Chicago, and would that have an effect on all the lakes if it did affect it ten miles off?

A. Certainly.

Q. Is it possible to divert a given amount at Chicago, say 4,000 cubic feet per second, and have the outflow in the St. Clair River go on forever undiminished?

A. No, sir.

Q. And it is your opinion that it must be absolutely certain, that the lowering effect of the diversion must affect the outflow in the St. Clair River?

Mr. Williams: I object to that question as leading.

A. Certainly.

Q. Now, what do you understand by the term "net supply" used in regard to the Great Lakes and the diversion of water?

A. By the term "net supply" I should understand it to mean the supply in any particular lake that its outlet had to take care of.

Q. And even though the amount through the outlet might vary, still the net supply would always remain the same? You understand that?

A. Yes.

Q. The net supply in any way would not be altered by the diversion itself, as you understand it?

Mr. Williams: Objected to as leading.

A. It would not.

Q. Are the rainfall, evaporation and absorption of the run-off in the drainage basin of the lakes, or the inflow from St. Mary's River, increased or decreased by the diversion at Chicago?

A. Neither.

Q. Now, can you give us an example or illustration of the effect that the outflow, say, through the St. Clair River would be affected by a diversion at Chicago, in any way?

A. I don't know that I caught the first part of that question.

(Question read.)

Q. As to its less, or greater—the relative relation between the outflow and the increase?

A. The St. Clair River is the natural outlet of Lake Huron,-Michigan, and any water diverted at Chicago would mean that it must come from the discharge of the St. Clair River; must be taken from that.

Q. In your experience have you made any measurements or have you any data in which, say, was given a certain amount of outflow through the drainage canal at Chicago, that you could figure out the effect it would have on the outflow of the lake?

A. Yes.

Q. Now, just give us, in a general way, what that system is that you would use?

A. First of all, would be the determination of the discharge curve of the St. Clair River.

Q. What would that be for?

A. For the purpose of finding out the discharge of the river corresponding to any particular lake stage.

Q. You mean by that, you get a formula to use and apply it?

A. A formula or curve which would give the discharge of the river for all stage of the lake.

Q. Now, can you tell us what the lowering of Lake Michigan and Huron would be, in inches, for a 10,000 cubic feet of diversion?

A. Very close to six inches.

Q. Could you tell us what percentage of the lowering in Lake Michigan the water in St. Mary's River at the foot of the locks will be lowered?

A. The lowering of the locks would be slightly less, about 20 per cent.

Q. Would the discharge of 4,000 cubic feet per second at Chicago effect the navigability of Lake Michigan or the Great Lakes?

Mr. Williams: Objected to on the ground it is leading and calls for a conclusion. I have no objection to the witness stating, if he has an opinion, what the effect of the diversion would be in so far as the lake level is concerned, but what that effect would be on navigation—I don't understand that the witness is qualified on navigation.

A. It would lower the water on all shoal places, which, of course, would be a detriment to the interests of navigation.

Mr. Williams: I move to strike out that part of the witness' answer referring to navigation in the last sentence thereof.

Q. What places would be effected on the Great Lakes? What do you term those places where a difference of a few inches of water may make a difference

A. The lower Detroit River is one of the critical places, and all of the west end of Lake Erie. Lake St. Clair; the northern end of Lake Michigan. Certain areas in Green Bay; the head of the Niagara River, and, in fact, the Niagara River to Port Day, and the lower St. Lawrence River below the Galops Rapids.

Q. You answered a short time ago, in regard to 10,000 cubic feet per second, the diversion would be a lowering of six inches?

A. A trifle over six inches.

Q. Now, the same proportion would hold good in 5,000 cubic feet, or any amount?

Mr. Williams: I object to the question as leading.

A. Yes.

Q. If Lakes Huron-Michgan were lowered a known amount and Lake Erie a known amount, what would be the lowering in the Detroit River, Lake St. Clair and the St. Clair River?

A. It would be substantially the same.

Mr. Williams: I object to the answer on the ground that it is not responsive to the question as put, and ask to have it stricken out.

A. (Continued.) The Detroit River and Lake St. Clair would be changed by very closely the amount that Lake Erie was changed; the St. Clair River would be changed by the amount that Lake Huron was changed—or very close to it.

Q. If a certain quantity of water is diverted in the drainage canal at Chicago, how much will the outflow of the Niagara and St. Lawrence Rivers be lessened?

A. They will be lessened by the amount of the diversion.

Q. Will Lake Erie be lowered?

A. It will.

Q. And the Niagara River?

A. And the Niagara River.

Q. Lake Ontario?

A. Lake Ontario and the St. Lawrence River.

Q. Do you know anything about the hydraulic measurements that have been taken in the St. Clair River since 1897, as to how much time has been spent, and the instruments, equipment and methods used? Just in a general way.

A. That is about three years—that is previous to my departure from the Lake Survey—previous to 1906. I am not quite sure of what has been done there since that time.

Q. Now, do you know as to the equipment they had for doing that work, and as to the instruments and methods they used at that time?

A. I do. The outfit was a very complete one, and the most of the velocity measurements on the cross-section were made with two meters.

Q. What were they?

A. They were Haskell Current Meters, used in such a way as to check each other.

Q. Who was in charge of the work there?

A. Mr. L. C. Sabin for the first two seasons.

Q. And who else?

A. And Mr. Murray Blanchard for the third season.

Q. Were they competent men for that work?

A. They were.

Q. Now do you know anything about the work done in the Niagara River?

A. I do.

Q. Just give us a general description of that?

A. The discharge measurements in the Niagara River were started by myself for the Board of Engineers on Deep Waterways in 1897. These observations were made—that is, the current observations were made—by Haskell Current Meters from the International Bridge. The following season beginning about midyear of 1898, that work was taken up by the United States Lake Survey with Mr. Shenehon in charge of the work, and was continued during 1898 and 1899, and into 1900, if I remember correctly. And as a check upon the observations made from the International Bridge, a second section known as the "Open Section" was selected at a point about 1,800 feet below the bridge and the discharge measurements of the river were made on that section and the two sections compared; that is, the discharge curves as determined from the observations at the two places were compared and they agreed within about a half of one per cent., as to the volume of discharge for any particular stage of Lake Erie.

Q. You consider that as accurate as it is possible to get it?

A. It is.

Q. And the St. Lawrence River, too?

A. The discharge of the St. Lawrence River was made at what is known as the "Three-point Section," by Mr. Shenehon, covering parts of two years.

Q. The same methods and systems applied?

A. Substantially the same methods, same instruments and same outfit employed in the work.

Q. And as far as your judgment is concerned the results are as accurate and trustworthy as may be obtained, are they?

A. They are.

Q. Now, with regard to the results of the volumes of flow for the various stages of Lakes Michigan, Erie, Huron and St. Lawrence, and other things that you have testified in regard to the results, within what scale of accuracy were they—the per cent.?

A. Within 5 per cent.

Q. Five per cent., is that the result in inches, or just what do you mean by that?

A. That the results were accurate within 5 per cent. That is, that the volume of discharge, for instance, is known within 5 per cent. of the absolute truth.

Q. You testified that a diversion at Chicago would lower the St. Lawrence River a certain amount?

A. Yes.

Q. Now, what would the corresponding lowering of Lake Ontario be for one foot, suppose, between Lake Ontario and Ogdensburg—be less than one per cent.?

Mr. Wiliams: Where would the one foot be?

A. You mean for a lowering of Lake Ontario for one foot?

Q. Yes.

A. It would be about .92 of a foot at Ogdensburg.

Q. It would be less than one foot?

A. Less than one foot.

Q. I want to ask your opinion regarding the propriety of using any existing data in regard to evaporation in the attempt to detect the presence or absence of the effect already produced on the lakes by the diversion made at Chicago since 1900?

A. It is hardly permissible to use that data at the present time.

Q. Have you any knowledge as to how large the error of those figures would be?

Mr. Williams: I object to the question on the ground that it is manifestly beyond the range of human knowledge to know, if they are not reliable, how unreliable they are.

A. Do you wish me to answer it?

Q. Certainly.

A. I should think that one might easily get into an error of 20 to 25 per cent.

Q. Now, the same question in regard to the precipitation, on the drainage of the Great Lakes?

A. Precipitation is a great deal better known. I think it is safe to say that the observations of the Weather Bureau give within 12 to 15 per cent.; that is, particularly the observations made during later years.

Q. Do you know particularly the extent of the observations made by that Bureau?

A. By the Weather Bureau?

Q. Yes.

A. They now have a large number of stations in the drainage basin of the Great Lakes, of course, they began with a few when the Weather Bureau started, and these have been increased, and for the last ten years they have had a pretty good number of permanent and volunteer observing stations.

Q. It might differ—the extent on the Great Lakes themselves—there are no stations on the lakes?

A. No stations on the water surface, no.

Q. Assuming a diversion of 10,000 cubic feet per second at Chicago, how long would it take 9/10 of the ultimate lowering in Lakes Michigan-Huron, due to this diversion, to take place?

A. About four and a half years.

Q. The same question in regard to Lake Erie, and the St. Clair River and Detroit and Niagara River?

A. Take nearly six years for Lake Erie.

Q. St. Clair River?

A. You asked Ontario, did you not?

Q. Yes.

A. And about six and a half years for Lake Ontario.

Q. Have you any figures on the St. Clair River?

A. The lowering of the St. Clair River?

Q. Yes. How long will it take?

A. The time?

Q. Yes.

A. The St. Clair River is controlled by Lakes Michigan and Huron, and the time required there would be substantially the time of those lakes.

Q. Do you know the fall of the Niagara River at Niagara Falls, as to the horse-power? Can you tell us what 4,000 cubic feet would be worth in horse-power at Niagara Falls?

Mr. Williams: I object to that question.

A. That is, as to the Falls?

Q. Yes, as to its use there as horse-power?

Mr. Williams: I want to state my objections. Not on the ground of immateriality, because that can be reached later, but on the ground that nothing has appeared to show that the witness is qualified to answer the question.

A. I should have to figure that out, if you want it for the Falls. That is, if you want it for the total fall in the Niagara River.

Q. Well, could you tell us what a thousand cubic feet per second at Niagara would be in horse-power?

Mr. Williams: I object to the question on the ground it is not complete.

A. The total fall there would amount to about 3,500 horse-power.

Q. You do not know anything about the fall available at Lockport and Joliet?

A. No, I do not.

Q. What would be the lowering of Lake Erie in inches of a diversion of 4,000 cubic feet per second at Chicago?

A. Two inches.

Q. And Lake Ontario?

A. An inch and two-thirds.

Q. This is reckoned on 4,000 cubic feet?

A. Four thousand, yes.

Q. The same proportion would apply on 5,000, 6,000 or 10,000?

A. The same proportion, yes.

Q. You testified as to Lake Michigan as 10,000?

A. As 10,000, yes.

Q. The change in the elevation that you testified to in regard to the level of the lakes, that would reach into every harbor and bay connected with the Great Lakes, would it not?

A. Certainly.

Cross-Examination by Mr. Williams.

Q. Mr. Haskell, what would be the effect on the level of Lake Michigan and Lake Huron by the diversion of 4,000 cubic feet per second at Chicago?

A. Can you give me time to figure it?

Mr. Reid: I think we took it for 10,000 instead of 4,000.

A. Two and a half inches

Q. Would the same proportion prevail with a discharge of any definite amount from nothing, say, to 20,000 cubic feet per second at Chicago, from Lake Michigan? That is, what I mean is, suppose there was a diversion of any definite amount at Chicago, that amount varying anywhere from nothing to 20,000 cubic feet per second, would the same proportion of lowering of level occur in Lake Michigan as is shown by the testimony you have given based on 4,000 cubic feet per second?

A. The figures that I have stated would be for mean level, substantially the mean level of those lakes.

Q. Yes?

A. It would be slightly less for lower stages and greater for higher stages.

Q. But would the same proportion exist as between the lowering of the level of Lake Michigan and Lake Erie, no matter what the diversion was up to say 20,000 cubic feet per second?

A. I don't think I get your question clear in my mind.

Q. We have a diversion of 4,000 cubic feet at Chicago which gives a lowering of Lake Michigan as you say of 2½ inches, and a lowering of Lake Erie of 2 inches, which is practically 4/5 of the lowering which occurs in Lake Michigan. Now, suppose the diversion was in amount from nothing to 20,000, would the same diversion take place in Lake Michigan as in Lake Erie?

A. Substantially so.

Q. How far from Chicago would you say that the effect of the diversion of 4,000 cubic feet per second would be noticeable and appreciable, following the chain of the lakes and the connecting rivers toward the Atlantic?

A. It must be appreciable throughout the entire lake system, in Lakes Michigan and Huron and the entire lake system below.

Q. To the Gulf of St. Lawrence?

A. Yes.

Q. Would it be appreciable in the Gulf of St. Lawrence?

A. It would be so infinitesimal that we would say no.

Q. Would it be noticeable, the lowering of Lake Michigan caused by the diversion at Chicago of 4,000 cubic feet per second, would that have any effect upon the level of Lake Superior?

A. No.

Q. Lake Huron, you would say, was effected the same extent as Lake Michigan?

A. To the same extent; Lakes Huron and Michigan are practically one lake.

Q. Now, taking the level of the water in St. Clair River would the diversion of 4,000 cubic feet of water in Chicago have any effect upon the level or the depth of the water in the St. Clair River?

A. It would.

Q. How much as compared with Lakes Huron and Michigan?

A. Well, nearly the same amount as Huron and Michigan.

Q. Would you care to express an opinion as to the percentage?

A. I have not worked it out in that form; it would be slightly less.

Q. Then I take it from the answers that you have already given that, in your opinion, the lowering of the level of Lake Erie would be substantially four-fifths of the lowering of Lake Michigan?

A. Yes, for mean stages.

Q. Yes.

A. Yes.

Q. Now, what would you say as to the level of Lake St. Clair, as compared to the level of Lake Huron—the effect of the level with a diversion of 4,000 cubic feet per second?

A. The effect on Lake St. Clair?

Q. Yes, sir. In your opinion would it be somewhere between the effect on Lake Huron and Lake Erie?

A. Yes.

Q. It would be slightly less effect—more effect on the depth, than the effect shown in Lake Erie, and less than shown by Lake Huron?

A. Would you mind repeating that?

Q. I mean, that the effect of the depth of the water in St. Clair River would be slightly less than the depth in Lake Michigan and Lake Huron?

Q. And slightly more than the effect of the depth of Lake Erie?

A. No; slightly less.

Q. The effect would be less than the effect upon the water in Lake Erie?

A. Yes. Because Erie, to a large extent, controls the Detroit River and Lake St. Clair.

Q. Well, suppose there is a diversion of 4,000 cubic feet of water per second at Chicago, which you say effects the depth of Lake Michigan to the extent of two and a half inches, to what extent would it effect the depth of Lake St. Clair?

A. Really it would be so close to the two inches, that you wouldn't need to bother about the difference.

Q. To the two inches?

A. Yes; of Lake Erie—perhaps I misunderstand you.

Q. Well, can you give your opinion as to the precentage of the 2½ inches lowering of the lake level of Michigan appreciable in Lake St. Clair?

A. I don't know that I see—

Q. Two and a half inches is 100 per cent.?

A. Is 100 per cent.

Q. Yes, sir. Now, what percentage of that effect would be shown in Lake St. Clair?

A. Practically 80 per cent. of it.

Q. And Lake Erie substantially the same?

A. And Lake Erie substantially the same, yes.

Q. What, percentage of that variation in depth would be

found in Lake Ontario as the result of the diversion of say 4,000 cubic feet per second?

A. I don't know that I see your point clear there. That is, what percentage?

Q. Yes.

A. Of the depth at Lake Michigan?

Q. Lowering of Lake Michigan, would be noticeable in Lake Ontario?

A. Would be noticeable in Lake Ontario?

Q. By the diversion of any quantity of water at Chicago?

A. About 70 per cent.

Q. Now, take the Detroit River. Assume a lowering of Lake Michigan by reason of diversion of water to the extent of one foot, or any definite lowering, to what extent would the depth of the Detroit River be affected as compared with the effect upon Lake St. Clair, or in connection with Lake Michigan, say, in comparison with Lake Michigan? What percentage of the lowering would be noticeable in the Detroit River?

A. About 80 per cent.

Q. What percentage of the lowering noticeable in Lake Michigan by reason of the diversion of a definite quantity of water would be noticeable in the Niagara River?

A. Well, that would depend upon the point in the Niagara River.

Q. Well, what part of the Niagara River is used for navigation purposes?

A. Clear down to Port Day, which is a short distance above the Rapids that approach the Falls.

Q. And how many miles?

A. About sixteen.

Q. Well, take it at Port Day?

A. Take it at Port Day?

Q Yes, sir.

A. Are you referring to Lake Michigan?

Q. Yes, sir.

A. Forty-one per cent.

Q. After you have passed through Lake Ontario and into the St. Lawrence River, what percentage of the lowering manifested in Lake Michigan would be noticeable in the St. Lawrence River due to a diversion at Chicago of any definite quantity?

A. That is, the percentage in the St. Lawrence of that in—

Q. In Lake Michigan?

A. —in Lake Michigan. Sixty-six per cent.; that is, in the St. Lawrence River down to the Galope Rapids.

Q. And from there on?

A. From there on I don't believe I have the data that I could express an opinion on that.

Q. Would it be less than the amount above the Rapids—66 per cent.?

A. Yes. For mean stages, yes.

Q. And would that—whatever the amount you determine to be the proper percentage—would that continue without variation to the Gulf, or would the effect decrease gradually as it neared the Gulf?

A. It would decrease.

Q. Until it reached zero, practically at the entrance of the Gulf?

A. Yes.

Q. Now, Mr. Haskell, let's go back to the St. Clair River and Lake St. Clair again, and having now clearly in your mind the purport of my questions, you stated substantially that there would be no difference between the effect observable in Lake Michigan and between that in Lake St. Clair, but you showed practically 20 per cent. between Lake Michigan and Lake St. Clair; where does that occur?

A. It occurs in this way: The St. Clair River is controlled by Lake St. Clair and Lakes Michigan-Huron.

Q. Yes.

A. —while the Detroit River and Lake St. Clair are controlled substantially by the stage of the water in Lake Erie.

Q. Well, could you have a drop of any amount in the St. Clair River and not have any in Lake St. Clair?

A. No. Still it might be masked by the stage of Lake Erie.

Q. Well, assume then, that at the connection of Lake Huron and the St. Clair River the effect of a diversion at Chicago is equally noticeable in Lake Huron and in the St. Clair River, would that continue to be true through the entire length of the River St. Clair down to Lake St. Clair, where the effect is only 80 per cent. of that noticeable in Lake Michigan?

A. Yes.

Q. And the drop then from the hundred per cent. lowering to the 80 per cent. lowering is at the outlet of the St. Clair River into Lake St. Clair?

A. It is distributed along the St. Clair River.

Q. Along the entire length of the river?

A. Substantially along the entire length of the river.

Q. All right. Now, this testimony that you have given with reference to these relative lowerings in these bodies of water, applies generally without reference to any specific gauge readings or discharge measurements or anything of that kind; you give that testimony based upon your knowledge of the lay of the lakes?

A. Yes.

Q. And you do not use, in arriving at these conclusions any specific discharge data?

A. No; only what is given by the United States Lake Survey.

Q. Well, what discharge data do you take into consideration in giving this testimony that we have just been going over now?

A. The date that has been obtained by the survey and that is in their published reports.

Q. But you use the specific data that you obtain from the United States Lake Survey reports in arriving at these percentages?

A. Yes.

Q. But you would be able to testify without any specific discharge data on the general proposition of the effect of the lowering being less appreciable as you approach the Gulf of St. Lawrence, and as you left Lake Michigan?

A. Yes, sir.

Q. And without going into the question of percentages?

A. Yes.

Q. You have testified, Mr. Haskell, with reference to the substantial accuracy of these discharge measurements and gaugings of the United States Government, and as exhibited to you, and have you had your attention called to these plates shown as Comp. Exhibits 1, 2, 3 and 4 lying on the table (indicating)?

A. Yes, I think those are the same ones. (Examining plates referred to). Yes.

Q. In giving your opinion as to the effect upon the level of Lakes Michigan and Huron of the diversion of 10,000 cubic feet per second, and 4,000 at or near Chicago, you have used the data contained in these gaugings and discharge measurements of the Government?

A. Not as they are given there; that is with one exception.

Q. Now, did you prepare yourself any plates or plats from which you arrived at the conclusions that you have testified to?

A. Yes. That is, this plate here (indicating), upon which I base my testimony, is one that is used by the International Waterways Commission.

Q. By whom was it prepared?

A. By Mr. Wilson.

Q. And the data from which it was prepared was obtained where?

A. The Lake Survey.

Q. The same source of information as used for a basis for the plates that I have called your attention to, as Government Exhibits 1, 2, 3 and 4?

A. Yes. That is, we may have used less than is given there. I won't be positive as to that, but the information comes from that source.

Q. And your testimony is based upon the computations made by you from the plate which you hold in your hand?

A. Yes.

Q. And used by the International Waterways Commission?

A. Yes.

Mr. Williams: Now, I would like to have that plate marked as "Haskell's Ex. 1, for identification," and attached to the deposition, so we will have it.

Plate marked "Haskell's Ex. 1, for Identification, 2/17/09 H. J. R. on X Ex."

Q. Now, is there, Mr. Haskell, to your knowledge, any information that is complete and reliable enough so that any estimate could be made of the effects of diversion of water from one of the Great Lakes, aside from the information which you, as a member of the International Waterways Commission and the Government have used, being the gauge readings and discharge measurements of the United States Government used as a basis for these plats or plates?

A. No; I think the only information available, from which the question can be worked out, are these data.

Q. Now, are you acquainted with the fact—if it is a fact—that the difference in the elevation between Lakes Huron and Erie has been nine-tenths of a foot less since 1886 than prior to that time?

Mr. Reid: That is objected to as not being proper cross-examination.

Q. What is the difference of elevation between the two lakes?

A. I don't think it is a fact.

Q. All right; it is not a fact. Then there is no explanation necessary?

A. No.

Q. Do you know that it has been so claimed?

A. Yes.

Q. But do you not think that that is true?

A. That is, that there has been a permanent change?

Q. That since 1886 it has been—there has been 9/10 of a foot less in difference of elevation than there was preceding 1886?

A. Yes. That is, I am aware that that does exist, but it is by no manner of means permanent.

Q. Well, now then, if it does exist, how do you account for that?

A. Due to the low stages of Lakes Huron and Michigan for a considerable period of time.

Q. And do you know why—have you any opinion as to why Lakes Huron and Michigan have had that low stage?

A. Lack of precipitation.

Q. Does that condition still prevail?

A. Partially so.

Q. You testified that in your opinion the data of the United States Government obtained from the Weather Bureau and the observation points under the jurisdiction of the Weather Bureau, were inaccurate to perhaps 12 to 15 per cent.

A. 12 to 15 per cent.

Q. For how many years back would you consider that to be true?

A. I should say for the last fifteen years.

Q. In your opinion that system of observation is increasing in efficiency from year to year?

A. From year to year.

Q. And would you say that 12 to 15 per cent. applied to the whole period, or to the latter portion of the period?

A. Well, I should say for the whole period of that fifteen years.

Mr. Williams: I think that is the extent of our questions, Mr. Haskell.

Re-direct Examination by Mr. Reid.

Q. Do you know what the water movement is—that is, if Lake Erie goes down a foot, how much does the water go down at Suspension Bridge,—at Whirlpool?

A. It goes down a foot at Lake Erie, you mean?

Q. Yes. Have you figured that out? Do you know?

A. Yes, I figured it out. I could not do any more than give a guess at it, without referring to the computations. (To Mr. Wilson.) Have you got one of those diagrams here, Mr. Wilson?

Mr. Wilson: I have not; it is in the report of the Commission on the Whirlpool Rapids.

Q. Then you have not it here?

A. I have not it here.

Q. It is greater or less than one foot?

A. It is greater than one foot.

Q. Now, does the position of any one of the lakes, or a pool, prescribed its lowering—its position in the chain?

A. Prescribe its lowering?

Q. Yes.

A. Yes.

Q. Well, do the lakes lower gradually to Montreal, is that what you mean by these figures you have been giving us here?

A. Yes. The actual lowering of the level would depend upon the discharge curve, as you go east, the increment of the discharge, would be greater.

Q. What I meant is, it gradually tapers off as far as Montreal, but beyond there the volume is so large—

A. Yes, below Montreal the volume is so large, compared to the amount of diversion that the effect is less.

Q. How does the increment in the Whirlpool compare with that at the head of the Niagara River?

A. The increment?

Q. Yes.

A. That is, per foot? It would be less.

Q. You answered the question before, it went greater as it went down. Now, is that as you understand? In your answer before you said it got greater as it went down?

A. Well, this question relates particularly to the Niagara River?

Q. Yes.

A. You see it does not apply to another lake, or another outlet. The increment of discharge for any particular section—when you mention the head of the Whirlpool Rapids that is a particular section in that river.

Q. That is protected by the motion, isn't it, of the water. Would not there be some difference?

A. The section is narower; that section is very much nar-

rower; very much narrower than the river where the discharge was measured.

Q. Yes. Wouldn't the area of the section control more from the fact that it was nearer the sea?

A. No, that would not make any difference.

Q. Now, the curves upon which you base your statements as to the lowering of the lakes, does not take into consideration the measurements made in 1908?

A. No.

Mr. Williams: There is one thing I would like to have, Mr. Haskell, go into the record, the definition of the word "increment." I don't think the court will know what we are talking about when we are talking about the "increment," and somebody ought to explain it?

A. We mean by the increment of discharge the additional quantity of water that is discharged per foot rise of the particular lake with which you are dealing.

Q. You mean the per foot rise or unit rise?

A. We usually term it the "per foot," and then if we want it in small quantities, we take the tenth of it, or in inches—to satisfy the lawyers—why we take the twelfth of it.

W. EDWARD WILSON, called as a witness on behalf of the plaintiff, being duly sworn, testified as follows:

Direct Examination by Mr. Reid.

Q. What is your name?

A. W. Edward Wilson.

Q. Where do you live, Mr. Wilson?

A. Buffalo, New York.

Q. What is your business?

A. I am secretary of the International Waterways Commission.

Q. How long have you been occupied in that position?

A. About two and a half years.

Q. Have you any profession?

A. Civil engineer by profession.

Q. What school are you a graduate of?

A. Graduate of Cornell University.

Q. What other positions or experience have you had in this line?

A. Why, since 1901-02 I was in charge of hydraulic meas-

urements on the St. Marys River; in 1903 I was in charge of the hydraulic measurements on the Niagara River, and for a period of three years I was in the Rocky Mountains at that time doing hydraulic work in addition to holding a position of assistant professor of Civil Engineering in the University of Utah.

Q. Did you finish giving your experience and positions?

A. Yes.

Q. Now what connection have you had with the hydraulic measurements on the Great Lakes and on the rivers?

A. That has partially been explained in the previous answer. Do you wish it stated again?

Q. Well, just on what rivers.

A. On the St. Mary's River and some work on the Niagara River.

Q. Well, just give us a short statement of the methods and results?

A. In 1901-2 I was in charge of the work on the St. Marys River in which we took up the measurements of the discharge of this river and in 1903, I think, the work on the Niagara River consisted of slope observation. In 1908 I made an investigation at Niagara Falls as to the effect of the diversion of water as caused by the Power Companies.

Q. Do you know anything about the local conditions at Chicago?

A. Very little.

Q. Now, is it possible to divert 4,000 cubic feet per second at Chicago without lowering Lake Michigan?

A. It is my opinion that you could not divert water through the Chicago Drainage Canal without lowering Lake Michigan.

Q. What effect would that have in the bays and harbors in Lake Huron?

A. Well, eventually it would lower every bay and harbor in the lake.

Q. Now, will you give us your idea and definition of "lowering" as used in this connection?

A. "Lowering," in this case means, with me, the change in level of Lake Michigan and Huron due to diversion at Chicago compared with the level of the lake without the diversion for the same period.

Q. The level of the lake may be, in fact, higher than it was before and still there be a lowering according to this definition?

A. According to this definition, yes sir.

Q. It is possible to divert 4,000 cubic feet per second at Chicago and have the outflow in the St. Clair River go on the same, undiminished?

A. It is not.

Q. What do you understand by the term "net supply"?

A. The net supply to any lake?

Q. Yes, or as it applies to Lake Michigan or Huron. Just give us a general definition and afterwards apply it.

A. Applied to any lake, it is the total quantity of water supplied to this lake, or in other words, it is the water yield to any lake. In the case of Lake Michigan and Huron it is equal to the discharge of the St. Clair River plus or minus the storage on the lake surface, or, it is equal to the precipitation on the lake surface plus the run-off from the streams of the water-shed minus the evaporation on the lake surface.

Q. Is that a constant quantity?

A. It is not; it varies from month to month and year to year.

Q. Notwithstanding that, is it still a concrete and tangible thing?

A. Yes, sir.

Q. Are the rainfall, evaporation, absorption, run-off, in the Drainage Basin of the Great Lakes, or the inflow of the St. Marys River increased or decreased by this diversion at Chicago? It does not alter these factors.

Q. Have you any method or can you compute the effect of diversion of water from a lake as to the amount it would lower in inches?

A. Yes, sir, I can compute it.

Q. Could you tell me what the lowering of Lake Michigan and Huron would be in inches for a 10,000 cubic foot diversion?

A. At mean stage, Lake Michigan and Huron would ultimately be lowered by a diversion of 10,000 cubic feet per second, about six and one quarter inches.

Q. Now, can you give us the same for Lake Erie and Lake Ontario?

A. For 10,000?

Q. Yes.

Mr. Williams: You are speaking now of a diversion at Chicago from Lake Michigan?

Mr. Reid: Yes.

Mr. Williams: And the effect of diversion?

A. The effect of diverting 10,000 cubic feet at Chicago would eventually lower Lake Erie about five inches.

Q. And for Lake Ontario?

A. The effect on Lake Ontario would be about four and one-quarter inches.

Q. Those would hold good for the same proportions for say 4,000 cubic feet per second and 6,000?

A. Yes, sir.

Q. What percentage of the lowering in Lake Michigan will the water in St. Marys River at the foot of the locks be lowered?

A. Well, the water will be lowered at the foot of the locks an amount slightly less than that on Michigan and Huron.

Q. What percentage at the critical points, and what do you consider the critical points?

A. In the St. Marys River?

Q. Yes.

A. I should say the locks at Ste. Marie and the improved channels along the St. Marys River.

Q. You gave these figures in regard to the mean stage. Now, what would be the effect on the high stages and the low stages?

A. The effect on these lakes?

Q. Yes; as to the larger or smaller; would it be greater when they are high or low?

A. For any particular lake?

Q. Well, any of these?

A. On Lake Michigan and Huron the effect would be greater as the stage becomes less, and vice versa.

Q. If a certain quantity of water is diverted in the Drainage Canal at Chicago, how much will the outflow in the St. Lawrence and Niagara Rivers eventually be lessened?

A. The same amount.

Q. Will Lake Erie be lowered?

A. Yes, sir.

Q. And Niagara River and the St. Lawrence River, as far as Ogdensburg?

A. Yes, sir.

Q. Did you do any of the work on the measuring of the outflow of the St. Lawrence River and the Niagara River?

A. No, sir. Other than my work in 1903, which did not take into consideration the discharge measurements specifically.

Q. Where was the work at that time?

A. At that time it was carried on between Buffalo and Niagara Falls.

Q. Have you any information as to the money spent in hydraulic measurements in the St. Clair River since 1897?

A. In a general way.

Q. Did you do any specific work in that line?

A. I did not do any on the St. Clair River. I did a little on the Detroit. My work has been principally on the St. Marys River.

Q. You consider the diversion of 4,000 cubic feet per second to 10,000 cubic feet per second through the Drainage Canal of Chicago would have any effect upon the navigable capacity of the harbors or lakes or bays of that section?

A. I do.

Mr. Williams: Objected to on the ground that it calls for a conclusion of the witness, and not facts, and, on the ground also, that the witness has not shown himself qualified to testify on questions affecting navigation.

A. Continued. It would lower the water in the entire system below Superior, and naturally cause a decreased draft for vessels.

Q., Now, where in the area you speak of would this likely effect the navigable capacities of these places?

Mr. Williams: I object to that question on the ground that it assumes a conclusion which has not been shown and on the further ground that it calls for another conclusion of the witness.

A. Lake St. Clair, at the foot of the Detroit River; on the shoals of the western part of Lake Erie. It would effect the Niagara River and the St. Lawrence canals and the St. Lawrence River.

Q. I want your opinion regarding the propriety of using any existing data regarding evaporation and an attempt to detect the presence or absence of the effect already produced by the diversion made at Chicago on the lakes since 1900?

A. It is my opinion that any deduction made from observations for evaporation would not be very reliable considering the fact that evaporation varies from month to month and from year to year. ——— In some months, the evaporation on, for instance, Lake Michigan and Huron is greater than the amount of precipitation in the lake surface and run-off of the streams. That also applies to Lake Erie and Lake Ontario.

Q. Take a diversion of 10,000 cubic feet per second at Chi-

cago, how long will it take 9/10 of the ultimate lowering in Lakes Michigan and Huron, due to this diversion, to take place?

A. Michigan and Huron—a little over four years.

Q. As to Lake Erie, St. Clair River and Lake Ontario?

A. Lake Erie, 9/10 of the effect would be noticeable in five or six years.

Q. Lake St. Clair?

A. Lake St. Clair would be somewhere between the time required for the lowering of Lake Huron and Lake Erie.

Q. Lake Ontario?

A. Lake Ontario, 9/10 of the effect would occur from five and a half to six and a half years.

Cross-Examination by Mr. Williams.

Q. In making your computation Mr. Wilson, as to the effect of a discharge or a diversion of 10,000 cubic feet from Lake Michigan at Chicago, that effect being as I understand —in making the computation, whatever the result—you must compute from some basis of discharge from Lake Michigan and Huron outflow?

A. I compute that quantity from a difference in discharge per unit rise.

Q. As shown by what?

A. As shown by this plate here, (indicating).

Q. That is the plate identified as "Haskell's Ex. 1."

A. Yes, sir.

Q. And which is to be attached to the deposition?

A. Yes, sir.

Q. Well, now, you use as a basis for your computation Haskell's Exhibit 1.

A. Yes, sir.

Q. And where did you get the data that is on that chart?

A. That data came from the United States Lake Survey.

Q. And is that the same data that is used, if you know, in the preparation of the plats or plates which have been heretofore identified as Complainant's Exhibits 1, 2, 3 and 4, being the plates on the table before us?

A. The results as shown on that plate are derived from a part of these observations.

Q. Did you have any information in the preparation of Haskell's Exhibit No. 1 not used in the preparation of the

Government Exhibits 1, 2, 3 and 4; you say you have used a part of the information shown on those plates?

A. Yes.

Q. Now, did you use anything that is not shown on those plates?

A. No, sir.

Q. So that the sole source of your information from which Haskell's Exhibit No. 1 has been prepared, is from the information derived from the Lake Survey?

A. Yes, sir.

Q. And the information shown on these charts?

A. Yes, sir.

Q. Is there any other definite and accurate information upon which to base conclusions upon the subject matter which you have testified about?

A. Not to my knowledge.

By Mr. Reid: Re-direct Examination.

Q. The Complainant's Exhibits 1, 2, 3 and 4 contain some more information than you have on Haskell's Exhibit No. 1, do they not?

A. They contain more data.

Q. Yes.

A. Yes, sir.

Q. Can you give us the statement in regard to the tapering off of the lowering or the effect of a certain diversion

Q. Now Mr. Wilson, you spoke of certain gorge sections in which the general rule which you stated might be reversed?

A. Yes, sir.

that you forgot to ask it on direct, I will not object to it, but if not, I will object to it as not re-direct examination.

Mr. Reid: Yes.

A. In a series of reservoirs, such as the Great Lakes are, the effect of diversions generally decrease as they go down to the source. There are occasions, however, in which—there are sections in which—the increment, or rate of change, in discharge per unit, is greater than at some definite point located above.

Q. Now, just explain why, and any instances you think of?

A. The best example that I know of is at Suspension bridge. That section the river is very narrow so that a unit rise of the river produces as less rate of change in discharge than say, at the head of the Niagara River where the width

of the controlling section is several times greater than at the Whirlpool.

Q. In regard to Haskell's Exhibit No. 1, you told Mr. Wil-
Mr. Williams: If you are asking this question on the basis
liams that you based your calculations on that. That does not take in the measurements made for 1908 does it?

A. No sir.

Re-cross-Examination by Mr. Williams.

in Chicago, and its effect as it goes toward the East?

Q. Have you in mind any other gorge section than the one mentioned by you at the Suspension Bridge in the chain of lakes?

A. There is one at the Whirlpool, that is in the Niagara River. There is another at the Rapids Plat in the St. Lawrence River.

Q. Now, take the gorge at the Suspension Bridge and the Whirlpool Rapids; is there any navigation carried on there?

A. There is a boat called the "Maid of the Mist" that navigates below the falls, but at these two sections—

Q. There is no navigation there?

A. No.

Q. And the Maid of the Mist would not be affected by the rise or fall of a foot?

A. Well, I understand that occasionally boats have gone down in that section, but not intentionally. That does not apply to the Rapids Plat; boats do navigate there.

Q. Yes, and do you know the depth of the St. Lawrence River there?

A. Well, I don't know that exactly. I know that boats drawing 5 or 6 feet navigate there.

Q. Pleasure boats?

A. Almost entirely pleasure boats.

Testimony of O. H. Ernst, taken before Anson S. Taylor, Commissioner, on February 18, 1909, at Washington, D. C.

Present for the complainant: Mr. Frank R. Reid.

Present for the respondent: Mr. John C. Williams.

O. H. ERNST, being first duly sworn to testify to the truth, the whole truth and nothing but the truth, testified as follows:

Direct Examination by Mr. Frank R. Reid.

Q. What is your name?
A. O. H. Ernst.
Q. Where is your residence?
A. Washington.
Q. What is your profession?
A. I am an army officer, retired.
Q. What is your title now?
A. Brigadier General, retired.
Q. I wish you would state what experience you have had, or what investigation or study you have made in matters regarding hydraulic measurements, and the same in regard to your knowledge of the conditions of the Great Lakes, and the waters connecting, and other waters in the United States; in a general way, the scope of your experience in these lines.
Witness: As an engineer?
Mr. Reid: Yes.
A. I graduated from West Point in 1864, and served in the corps of engineers of the army until I retired under operation of law in 1906. After a short service in the Civil War, I was engaged on the Pacific Coast on fortifications, and surveys until 1868. From 1868 to 1871 I was stationed at the Engineer's School of Application at Willetts Point, where, among other things, were more or less studies of hydraulics and topography. From 1871 to 1878 I was instructor of Practical Military Engineering at West Point Military Academy, where I performed the duties of architect of the more important structures there and in charge of water works. From 1878 to 1886 I was stationed at St. Louis in charge of the River and Harbor District, with headquarters at that place, including the Mississippi River. From 1884 to 1894 I was a member of the Missouri River Commission, and from 1888 to 1894 I was a

member of the Mississippi River Commission, and later on I was President of that Commission, from 1902 to 1905, I think, or perhaps from 1903 to 1906, yes, that was it. From 1886 to 1889 I was stationed at Galveston, Texas, having charge of the rivers and harbors of the Texas Coast. From 1889 to 1893, I was here in Washington as Aide-de-Camp to President Harrison, and had charge of the public buildings and grounds here, and was a member of the Lighthouse Board. From 1893 to 1898 I was in command of the Military Academy at West Point. I served in Porto Rico and Cuba during the Spanish War of 1898. In 1899 I was a member of the Isthmian Canal Commission, appointed to investigate all routes for the Canal across the Isthmus. I served on that Commission until 1901. From 1901 to 1905 I was stationed at Chicago, having charge of the rivers and harbors in that district, of the local works there, and was also division engineer of the Northwest division, which included the Great Lakes system as far east as Erie, Pennsylvania. During that time I was Chairman of a Board of Engineers appointed to make surveys and estimates for a waterway 14 feet deep from Chicago to St. Louis. From 1905 to 1906, I was again a member of the Isthmian Canal Commission, and in 1905 I was appointed on the International Waterways Commission. I am still Chairman of the American Section of that Commission. That Commission has made a report on the Chicago Drainage Canal. I believe that covers my record.

Q. State what the scope of your duties was in regard to the Great Lakes and bodies of water connecting, or the connecting waters; what you had to do, your observations, studies and just what came under your direction and observation.

A. I had general supervision of all the districts in the region I speak of, the construction districts, and in connection therewith it was necessary for me to know more or less about the needs of navigation in order to fix on the dimensions of channels and the propriety or necessity of their construction.

Q. In that matter, it would come under part of your duties to know about the diversion of water from other bodies of water, the decrease or increase of water levels, hydraulic measurements and things of that nature?

A. Yes. I had to examine into these questions.

Q. State in a general way what you had to do or what came within your knowledge in these capacities in regard to navigation and commerce on the Great Lakes.

A. Well, I had to become familiar with the size of vessels employed, the amount of commerce that existed; in other words, the requirements of navigation, and I made some original studies in connection with the Illinois River, ascertaining what could be done in that river with the volume of water such as was being diverted down that river, what use could be made of it for navigation purposes.

Q. State what came under your observation with regard to vessels and the loads they were to carry and the different methods of handling these loads and vessels.

A. I visited the ports where the great freight carriers loaded and unloaded and had conversations with the managers of that business, and ascertained from them their needs and their prospects. I have overhauled the official list of vessels published by the United States Government to ascertain how many vessels of deep draft were navigating the Great Lakes, and what their freight tonnage was.

Q. Did you become acquainted with the drafts that the different vessels draw, and the loads, and things of that nature?

A. Yes, sir.

Q. Leaving that for a moment, I want to ask you if you know of the local conditions in the vicinity of Chicago, as in the Chicago and Calumet Rivers, and in and about where the Chicago Drainage Canal is located? Do you know what effect the diversion of say 4,000, 5,000, 10,000, or 14,000 cubic feet of water per second would have on Lake Michigan, if diverted into the Drainage Canal?

A. I think I do, yes.

Q. What would it be on Lake Michigan?

A. I have in mind—

Mr. Reid: As to whether it would lower it, or what effect it would have.

A. It would be lowered.

Q. State the effect it would have on Lake Michigan or the other Great Lakes.

Witness: For a given amount?

Mr. Reid: No, just generally.

A. It would lower the whole system of Great Lakes below the St. Marys River.

Q. That would include all the bays, inlets and harbors connected with the Great Lakes?

A. Yes, everything.

Q. Could you state what effect the diversion of 4,000 cubic

feet per second out of Lake Michigan into the Drainage Canal would have on Lake Michigan?

Mr. Williams: The question is objected to. I have no objection to your asking for his opinion, but object to your asking for absolute fact, unless the proofs or data from which he speaks are submitted.

A. The figures which I have in mind are the amount that would be lowered by 10,000 cubic feet per second. That is about 52/100 of a foot, say 6¼ inches.

Q. Would the same proportion hold good as to 4,000, 5,000, 6,000, or any other number of feet?

A. Yes.

Q. Could 4,000 cubic feet per second be diverted at Chicago without lowering Lake Michigan?

A. No.

Q. What do you understand is the meaning of the term "lowered"?

A. I mean relative lowering. Of course, the level of that lake is oscillating, due to winds, varying barometric pressure, varying rain fall and evaporation. When I say lowering, I mean that it is lower than it would be without that diversion.

Q. It is possible that the lake may really be higher in feet and inches, and still be lower in your definition?

A. Yes.

Q. Is it possible to divert 4,000 cubic feet per second, and have the outflow in the St. Clair River go on forever undiminished?

A. No, sir.

Q. What is the net supply, as you understand it, in regard to bodies of water?

Witness: What is meant by that expression?

Mr. Reid: Yes.

A. To my mind it means the quantity of rain fall diminished by the amount of evaporation.

Q. Is that a certain or tangible thing?

A. Yes.

Q. Are the rain fall, evaporation, absorption, run-off in the St. Marys River increased or decreased by the diversions at Chicago?

A. Not at all.

Q. If Lakes Huron and Michigan are lowered in a known amount and Lake Erie in a known amount, what will be the lowering in the Detroit River, Lake St. Clair, and the St. Clair River?

A. I am not prepared to answer that question.

Q. Could you give us the lowering of Lake Erie and Lake Ontario, with a diversion of 10,000 cubic feet per second in Chicago?

A. If you will allow me to refer to memorandum. I do not carry these numbers very well in mind. (No objection being interposed, witness was permitted to refer to the memorandum.) For Lake Erie about 45/100 of a foot; for Lake Ontario, about 35/100.

Q. If a certain quantity of water is diverted in the Drainage Canal, how much will the flow of the Niagara and St. Lawrence Rivers be diminished by that diversion?

A. By that exact amount.

Q. In your experience you have had occasion to reckon upon and take into consideration evaporation in regard to the effect it might have on bodies of water, have you not?

A. Yes, sir.

Q. I will ask you if in your judgment the evaporation should be considered in an attempt to detect the presence or absence of the effect already produced in the lakes by the diversions made at Chicago since 1900?

Mr. Williams: Question objected to on the ground that it is leading.

Mr. Reid (continuing): And can you give us your opinion as to how exact any data of this kind is?

Mr. Williams: The objection stands to the whole question as completed.

A. Why, of course, evaporation is an exceedingly important consideration, but you mean, I suppose, whether I think that the result of direct observation on evaporation, the amount of evaporation, is of use?

Mr. Reid: Whether that is certain or accurate enough to take into consideration.

Witness: No, nobody knows what the volume or amount of water evaporated is.

Q. Have you any information as to how much the error might be in regard to this data?

A. No; it might be very great; it might be 20 per cent., more or less. Nobody knows even approximately what that evaporation would be.

Q. In regard to precipitation and its effect in the same way, that is not well determined, is it?

A. The rain fall observations are made at isolated points over this large area. They can not be made on the areas occu-

pied by the lakes themselves. The average taken over that entire basin may be a fair average or may not.

Q. I want to ask you with regard to the boats. Can you give us the figures as to how many boats plying between Lake Superior and the lower lakes or the lakes below Superior are capable of loading to 19 feet?

A. I can give you these figures with close approximation, and I can tell you how I obtain it. I went over the official list of merchant vessels published by the government for 1906, took out all the vessels that had a depth sufficient to enable them to load to that draft. I then went to the Lake Carriers' Association and obtained from them the list of vessels that had been added during the season of 1906, and which would not appear in that list. That gives me the vessels for 1907, which is what I have here.

Mr. Williams: Before the witness answers further, in view of what he has already said as to his source of information, I object on the ground that it is not the best evidence on the subject matter upon which the witness is being interrogated, as the reports referred to by him and the persons communicating to him the information should be produced.

Witness (continuing): Four hundred and eighty-three.

Q. With regard to 20 feet?

Mr. Williams: Please note the same objection.

A. Four hundred and thirty-six.

Q. Twenty-one feet?

Mr. Williams: Same objection.

A. Three hundred and ninety-four.

Q. Can you give us the figures on how many tons of freight are carried by all boats capable of loading to 19 feet, traversing the routes as I have before indicated?

Mr. Williams: Same objection.

A. The percentage of freight in such vessels is about 70 per cent. of the total freight carried. In 1907 the total freight which passed through Detroit River was 71,226,895 tons, from which it is computed that about 50,000,000 tons were carried in boats drawing 19 feet or more in that year.

Q. What proportion of this freight is carried under conditions of maximum loads as limited by draft in the lower levels of the lakes, of the Sault or St. Marys River, and in the lower lakes and rivers to Chicago or Buffalo, or other lake or river ports?

Mr. Williams: Same objection.

A. 36,000,000 tons.

Q. Can you give us the proportion of what is known as up-bound freight and the other way?

Mr. Williams: Same objection.

A. The freight bound East is about 80 per cent. of the total. Up-bound 20 per cent.

Q. Which is up-bound?

A. The west-bound. The percentages are:

1904, 76 per cent.

1905, 83 per cent.

1906, 80 per cent.

1907, 78 per cent., about 80 per cent.

Q. You gave us some figures in regard to the tons of freight carried by boats capable of loading to 19 feet, I want to ask you the figures regarding boats capable of loading to 20 feet.

Mr. Williams: I make the same objection.

A. About 29,000,000 tons.

Q. Can you give us the way this freight is carried by boats loading to 20 feet, the proportion, through the routes indicated for the 19 foot boats?

Mr. Williams: Same objection.

A. When I say the total freight, I speak of all the freight.

Q. For all the boats?

A. Yes.

Q. When a large freighter is loaded in Lake Superior for Lake Erie ports or Lake Michigan ports, what determines the depth to which she is loaded?

A. The depth of water in the locks and the Sault and channels below. The depth of water on the mitre sill on the Poe lock is 19 feet usually. Nineteen feet is the depth at low water. They keep in telegraphic communication at the Sault and when a boat is loading at the west end of Lake Superior, they will load her down deeper than 19 feet if they find they can do so with safety.

Q. You mean by that the limiting depth?

A. You may say it does not go below 19 feet; it sometimes goes above 19.

Q. You mean that is the limiting depth?

A. That is what fixes the draft to which they can load these ships, the freight carriers.

Q. By mitre sill, do you mean the highest point?

A. The highest point of the lock, yes.

Q. What about the lower level? How do you consider that in saying that the mitre sill is the one that controls?

A. I mean by 19 feet over the mitre sill, the least depth to be found in the lock.

Q. The lock or any body of water changes and fluctuates, does it not, on account of storms and other causes?

A. Yes.

Q. Do you consider that the loss of depth of two, four or six inches affects the navigation any way?

Mr. Williams: I object to the question as leading, incompetent and also on the ground that it calls for a conclusion and not for a fact.

A. I think it does.

Q. Is the loss more serious under these conditions than it would be otherwise?

Mr. Williams: Objected to on the ground that it is leading and calling for comparison.

A. I do not think it is a very important consideration. If it affects it in any way at all, I think it would make it a little more serious.

Q. Do you know the dimensions of the present largest freight carriers of the lakes, traversing the water below Lake Superior?

A. There are three new boats.

Q. How much freight in tons is carried on these vessels on each inch of draft between 19 and 21 feet?

Mr. Williams: Objected to on the ground that it calls for information which witness does not purport to give as from his own personal knowledge.

A. There are three new boats, the William M. Mills, William B. Kerr and the Le Grande De Graff. They are all the same size, and are the largest freight carriers now on the Great Lakes. They are each 607 feet long over all, beam 60 feet; depth 32 feet. Each has a gross tonnage of 7,970 and a carrying capacity of 13,000 tons. About 85 tons is carried in one of these vessels on each inch of draft between 19 and 21 feet.

Q. For a boat of less than 19 feet, would the same proportion hold good?

A. Yes.

Cross-Examination by Mr. Williams.

Q. All the information that you have given with reference to the vessels navigating the Great Lakes, their tonnage, and their dimensions, has been based on information obtained by

you from other sources, partly from official records and partly from records of private concerns, associations, etc.?

A. Yes, sir.

Q. And no part of this evidence that you have given with reference to these matters is based on your own personal knowledge?

A. No, sir.

Q. You spoke of the fact that Lake Michigan was subject to oscillations on the surface of the lake, do you know the extent of these oscillations?

A. Yes, I can give you that by reading a couple of paragraphs in this report by the International Waterways Commission, of which I am a member, or I can refer you to them. Shall I read them?

Mr. Williams: So much as is in answer to my question. I asked to what extent is the surface of Lake Michigan subject to oscillations.

Gen. Ernst: It will oscillate two or three feet in 15 minutes sometimes.

Q. And these oscillations are caused by weather conditions largely and barometric pressure?

A. The oscillation that I just spoke of is the barometric pressure. That is what is called a seiche.

Q. You stated, General, that in case of a diversion of 10,000 cubic feet of water per second from Lake Michigan, the level of the lake would be lowered to the extent of 52/100 of a foot, and I also understood you to say that the withdrawal of any larger or smaller amount would cause a corresponding variation in the level of the lake?

A. Yes.

Q. Is that true precisely or only approximately?

A. I think you may say it is true absolutely. The curve of relation between the discharge and the level is a straight line, plotted as carefully as it can be plotted.

Q. Would you say, for instance, if 100,000 cubic feet of water was diverted from Lake Michigan, the variation in the lake level would be just ten times as great as the variation caused by a diversion of 10,000 cubic feet per second?

A. I think approximately that is true.

Mr. Williams: That is the reason I asked you before whether it is exactly true or approximately true.

Witness: It is approximately true. It is within the limits of our observations.

Q. Does it make any difference what the stage of the water

in Lake Michigan is as to what effect a diversion of 10,000 cubic feet or any definite quantity of water from the lake at Chicago would have on the lake level?

A. Yes.

Q. In your opinion, the effect testified to by you of 52/100 of a foot by the diversion of 10,000 cubic feet is assuming a certain definite stage of the water?

A. The average stage.

Q. Averaged for what periods?

A. The periods covered by the records, what is known as the mean stage of the lake.

Q. And these records include what year last?

A. From 1860 down to date.

Q. Including the year 1908?

A. We will say 1907, or perhaps 1906. They were made a couple of years ago. The mean average stage from 1860 to 1906.

Q. That is 47 years?

A. Yes.

Q. Your estimates are based on what data, General?

A. Upon the reports of the Lake Survey.

Q. Are they the same reports as those used as a basis for the preparation of the plates that have been referred to in the testimony heretofore given by Mr. Noble?

A. I think there has been some revision since those reports that have been used in the preparation of those plates, but I am not positive.

Q. In the making of the estimates and the forming of the conclusions of which you testify, did you obtain any information which was not available and used in the preparation of these plates?

A. No.

Q. Do you know of any other record of discharges and gauging that afford sufficient accuracy to enable you to make any computation that would be reliable, and to which you would want to testify as to the effect of diversions?

A. I rely entirely upon the observations on the lakes in the opinions that I have given, absolutely.

Q. And you consider them the best in existence?

A. Yes, sir.

Q. What percentage of accuracy would you ascribe to the records of precipitation in the area covered by the water shed of the Great Lakes?

A. I do not know. That may be about 20 per cent. I do not know anything about that and nobody else does.

Q. Do you consider the records of discharges which you have used as a basis for your computation as absolutely correct?

A. Well, when you say "absolutely," no. It is impossible to measure water with absolute precision. There are very close approximations.

Q. What percentage of accuracy would you ascribe to those computations?

A. I suppose within 5 per cent.

Q. Assuming that Lake Michigan and Lake Huron were lowered in a definite amount, say one foot, by reason of the diversion occurring at or near Chicago, what effect would such a lowering have upon the depth of the St. Clair River as compared with the lowering in Lakes Michigan and Huron?

A. Approximately, I think, it would lower a foot at its head, and a somewhat less amount at its foot.

Q. Have you memorandum or data or could you make a computation to indicate the difference in the effect at the foot of the St. Clair River as compared with its head, assuming a loss of a foot in the Lakes Michigan and Huron?

A. It has been worked out. I think I could find it for you. I haven't it in my mind just now.

Q. Could you give the percentage?

A. Not now.

Q. How much work would it involve?

A. I could not tell you. I would have to look that up.

Q. Have you an opinion and can you state approximately what percentage of the effect perceptible in Lakes Michigan and Huron due to diversion at or near Chicago would be observable in Lake St. Clair?

A. That is the same question. I am not prepared to give you the exact relations.

Q. Would Lake St. Clair be approximately the same level as the foot of St. Clair River?

A. Yes.

Q. The entire lake?

A. Yes.

Q. And what would you say as to the Detroit River?

A. The head of the Detroit River is the same level of Lake St. Clair.

Q. And the foot of it?

A. There would be a slight depreciation of the effect.

Q. For Lake Erie you gave us figures on the basis of 10,000 cubic feet, now for Lake Michigan would the same proportion apply there?

A. Yes.

Q. What would you say as to the effect observable in Niagara River?

A. There would be a diminution there again.

Q. As you approach Lake Ontario there would be a diminution of the effect observable?

A. Yes.

Q. And Lake Ontario would bear the same relation upon the hypothesis of 10,000 cubic foot diversion?

A. Yes.

Q. And the St. Lawrence River, I take it that at the head of the river the effect would be practically the same as Lake Ontario?

A. In the lowering of the level, yes.

Q. And that effect depreciates down to the Gulf?

A. No, that does not follow. Then comes the difficulty of cross-sections and slopes.

Q. Except as to the narrowing effect of the river in some cases, the general tendency would be to depreciate in effect until it dropped down to the Gulf, if you did not take into consideration those parts of the river that had a great variation of slope?

A. If you can omit those, but you can not do that.

Q. I take it that by the time you have reached the Gulf of St. Lawrence, the effect of the diversion is scarcely perceptible?

A. When you get down into tidal water, I do not know that it is.

Q. In order to make an accurate determination at any given time of the effect of any definite diversion from a lake, say Lake Michigan at Chicago, I mean the effect on the lake level, would it not be necessary at that particular time to take into consideration the evaporation and rain fall?

A. No.

Q. You could not take them into consideration?

A. No; not directly. Of course the whole question is dependent on them absolutely, but their relative value is what we want. We can get that by discharge measures.

Q. Suppose you wanted to know the effect today on the level of Lake Michigan of the diversion of a definite amount of water, not the ultimate effect or general effect, or the aver-

age effect, but what is the effect today on the lake level, would it not be necessary to take into consideration the rain fall and evaporation?

A. No, except as to their relative values. If you should take absolute values of these, you might get results which would be preposterous.

Q. Is it a fact or is it not that the reason you will not take them into consideration in arriving at a conclusion as to the actual effect at a given time, is that the information concerning them is so indefinite and unreliable that you could not with safety testify?

A. That is a reason which is certainly conclusive, but if you ask me whether any man can go out and ascertain the change of level in Lake Michigan today without any observations before or after, I would say he can not do it. Let me explain that subject a little more fully. I would like to read a couple of paragraphs from this report.

Mr. Williams: Would you like to read them in as a part of your testimony?

Witness: Yes.

Mr. Williams: This is not in response to a special question, but is an additional statement by witness in explanation of the difficulty of ascertaining the effect of diversions upon the level of the lake by any brief or limited observations.

General Ernst requests the privilege of reading the two paragraphs Nos. 22 and 23 of the Report of the International Waterways Commission of the Chicago Drainage Canal. Counsel for the respondent signifies his willingness to have the paragraphs read. Counsel for the petitioner requests the witness to abstain from reading the paragraphs, unless counsel for the respondent makes the special request therefore and adopts it as part of his cross-examination.

Q. I will ask you whether or not you have heretofore made any statement bearing upon the subject of this inquiry which you would like to incorporate in this record as an additional explanation of the subject matter about which you have testified?

A. I would like to explain what I mean by the oscillations of the Great Lakes.

Mr. Williams: I will ask you to make that explanation.

Witness, reading from the report of the Chicago Drainage Canal by the International Waterways Commission, paragraphs 22 and 23, as follows:—

"22. Variations in the level of the lakes' surface, due to

winds and to change of barometric pressure, are frequent and irregular and at times violent. Variations of more than six inches are very common, often occurring hourly for many hours in succession, while variations of two or 3 feet within an hour are not uncommon. Besides these irregular variations there is a regular annual variation due to difference in rain fall, evaporation, and run-off, the water level being highest in mid-summer and lowest in mid-winter. The levels are affected also by the greater or less severity of the winter and the consequent greater or less decrease in the discharging capacity of the outlets by ice. In order to study the annual oscillations it is necessary to eliminate the irregular oscillations, and that is accomplished by using the average levels for a month. Using the monthly mean levels it is found that the regular fluctuation in Lake Huron-Michigan usually does not exceed two feet in any one year, but in a long series of years there is a great difference in the height to which high water will rise. The highest high water (monthly mean) recorded for that lake was in June, 1886, and the lowest high water in June, 1896, the difference between the two being over 3¼ feet. The first is what navigators of the Great Lakes call a high-water year and the second a low-water year.

23. It is evident that the average level of the lake may be lowered considerably without the change becoming immediately apparent, and that fact has been used as an argument to prove that the lowering caused by the Chicago Drainage Canal is of no consequence to those interested in navigation. Since they can not see it they will not know it and will not feel it. The argument is fallacious. It is true that they can not see it immediately, but they will soon feel it and will know it through the most costly means of acquiring knowledge—the injury to their material interests. The oscillations will remain the same as before, but low water will fall lower and high water will rise less high. The average draft of vessels must be diminished by the amount that the average level is lowered unless the depth be restored by remedial works."

Q. These paragraphs were written by you?

A. Yes.

Q. Is there an expression of opinion there contrary to the opinion expressed by you at a previous time?

A. No.

Q. Were you a member of the Board of Engineers which reported on the proposed waterway from Lockport to St. Louis?

A. Yes.
Q. You were Chairman of that Board, were you not?
A. Yes.
Q. Did not the Board, of which you were Chairman, state in its report that navigators were not likely to find out that a lowering of six inches had occurred in Lakes Michigan and Huron?
A. No; here is what I said, or the Board said. I may say that I wrote both these reports:
"A permanent average lowering of six inches in the lake's level therefore is not easily observable, and will probably not be noticed by navigators. Nevertheless, the effect is real and important." Now a great deal of weight has been put on that language "probably not be noticed by navigators." You may undermine the foundations of a man's house and he will not notice it, and in that sense the navigators do not notice that their foundations are being undermined. There is nothing inconsistent between this statement and that statement, not a bit.

CURTIS McDONALD TOWNSEND, a witness called on behalf of the complainant, having been first duly cautioned and sworn, testified as follows:

Direct Examination by Mr. Reid.

Q. What is your name?
A. Curtis McDonald Townsend.
Q. Where do you live?
A. Detroit, Michigan.
Q. What is your profession?
A. I am army engineer; Lieutenant Colonel of engineers.
Q. How long have you been employed in that capacity?
A. Since 1879.
Q. What has your experience been?
A. Well, I have been very generally employed in the improvement of rivers and harbors of the United States.
Q. State in a general way the geographical locations that you have been in.
A. At the present time?
Q. No, in your experience.
A. Oh, my experience; well, as assistant I had work on the rivers in the vicinity of Baltimore, of Petersburg, Vir-

ginia, and of Charleston, West Virginia. I then was an assistant to the engineer commissioner in the District of Columbia. Afterwards was Quarter Master at Willets Point in charge there of constructing some houses. I afterwards was assistant in charge of the construction of the tunnel for supplying the City of Washington with water. I then was in charge of the third district on the Mississippi River. Then I had charge of the Grand Rapids district, and the rivers and harbors on the east shore of Lake Michigan. Then the Rock Island District, in charge of the upper Mississippi River from St. Paul to St. Louis, or to the mouth of the Missouri. Then was in charge of the harbor of Manila in the Philippines. Then returned to this country and had charge of the rivers and harbors in the Cleveland district; the harbors on Lake Erie from Toledo to Conneaut, and from there was placed in charge of the Detroit district, which has charge of the waters connecting the Great Lakes and certain harbors in Michigan, on Lake Huron and Lake Erie.

Q. How many years have you been on the Great Lakes altogether in this line of work?

A. About five years.

Q. Now state of what your work consisted.

A. The improvement of harbors, which would consist at certain times of dredging those harbors to certain depths; at other places including building breakwaters, which would protect the entrance to certain streams.

Q. Particularize a little more.

A. Well, for instance when improving the harbor at Toledo, there the work consisted simply of dredging a channel in the Maumee River from Toledo to Lake Erie. In improving the harbor of Conneaut, the work there consisted of dredging into the river at that place and also constructing breakwaters that would protect this dredged channel. At Cleveland the work consisted of building a breakwater and of dredging a harbor behind it. The work I am now employed upon consists in deepening the channels which are connecting the Great Lakes and building a lock at the Sault Ste. Marie. That is the principal work.

Q. What do you do in accomplishing this result in regard to measuring and obtaining knowledge of the water, and things of that kind?

A. The first thing that is necessary to do is to make a survey and determine the depth of water that you have in your channel; then to determine the material of which the

bottom is composed. Then you have to make a contract for either excavating the sand or rock.

Q. Now in regard to the level of the water there, does this work which you do necessarily take into consideration the levels?

A. That is the first necessary thing in a survey is to know the level of the water, so that you can determine what your depths are.

Q. In doing this, you not only know the level of the water in the particular places, but in connecting bodies of water?

A. We have to know the levels of water at the point where we are doing our work, and its relation to the levels of the connecting lake.

Q. You actually had those things under consideration when you were doing this work?

A. Yes.

Q. And that is part of the work?

A. We have to arrange our work on a certain datum plane.

Q. I show you Complainant's Exhibit No. 5 of date April 19, 1909, and ask you to mark the limits of the district in which you are now in charge; and when you mark it state where the marks are being placed.
of the district.

A. The head of St. Mary's River marks the northern limit

Q. Mark that No. 1.

A. That is Number 1. The next limit of the division are the Straights of Mackinaw between Lake Michigan and Lake Huron.

Q. Mark that No. 2.

A. Marked No. 2. The district then includes Lake Huron and St. Clair River, Lake St. Clair, the Detroit River and the harbor of Monroe, which is the southern limit of the district.

Q. Mark that No. 3.

A. That is No. 3.

Q. Have you named all the geographical names of the bodies of water within that district?

A. No. There have been improved in this district in the upper St. Mary's River, three localities. Then there have been constructed some locks, the Whitsall and Poe locks at the Sault Ste. Marie. The channel from the Sault Ste. Marie to Mud Lake has been improved and is now under improvement. There have been certain spots between Mud Lake and Detour dredged. Then there has been improved along the shore of Lake Huron the harbor of Cheboygan, Alpena, Saginaw

River; a breakwater at Harbor Beach, Sebewaing. Then the St. Clair River has been improved in sections; the Black River, the Pine River, Bell River. Then Lake St. Clair has been dredged practically across the lake. Clinton River emptying into Lake St. Clair has been improved, and the Detroit River has been improved particularly in the vicinity of the Limekiln Crossing. Then the furtherest southern work of the district is the harbor of Monroe.

Q. Now in regard to Lake Huron, was there work done at the foot of Lake Huron?

A. Yes, a channel has been excavated at the entrance to St. Clair River at the foot of Lake Huron.

Q. You stated in a general way the improvements and the places that have been improved in your district. Now state the fact as to whether or not there is practical navigation going on in your district?

A. Yes, sir, there is a very considerable navigation going on in the district.

Q. Could you give us in a general way of what that navigation consists?

A. Well, during the year 1907, which is the maximum, there was in the vicinity of fifty eight million tons of freight passed through St. Mary's River; and over sixty million tons of freight passed through the Detroit River; also through the St. Clair River.

Q. Have you observed the vessels that carry the freight through your district, as to their method of loading?

A. Yes, I observed the depths to which they have loaded.

Q. State to what depths they load.

A. They load to as great depth as we will allow them to load.

Q. What has that been?

A. Well, the last year it ran from 19 to 20 feet.

Q. What limits the nineteen or twenty feet?

A. The depth that we have on the floor of the Poe Lock is now our limiting depth. And we have a second limiting depth at Bar Point, which is at the end of the Detroit River; is the entrance to Lake Erie. The third limiting depth would be at Ballard's Reef, a crossing which is just a little further up in the Detroit River.

Mr. Williams: Q. Where is that Ballard's Reef?

A. That is several miles up the Detroit River, from the mouth.

Q. Bar Harbor is at the mouth?

A. Bar Point is at the mouth. That is in Lake Erie.

Mr. Randolph: Q. Is Bar Point the second limiting point?

A. Bar Point is the second limiting depth. Of course I will say the second limiting, it will be the same as the first limiting point.

Mr. Reid: Q. What information do you give the lake carriers?

A. There is published at the Sault Ste. Marie the depth that we allow in the Poe Lock; that is published, given to the public.

Q. Assuming that 10,000 cubic feet of water is drawn from Lake Michigan at Chicago, and the drawing of that 10,000 cubic feet per second lowered the lake, the level, say five inches. Would that have any effect on the level in your district?

Mr. Williams: Just a moment, before that question is answered: I want the record to show that I object to the question, first on the ground that it is not intelligible and second on the ground that the witness has not shown himself to be qualified to testify on the point of the effect of diversions at different points?

A. Yes, it would.

Q. Will you give us to what amount?

Mr. Williams: I object to the question on the ground that it is not intelligible; and second, on the ground that the witness has not shown himself to be qualified to testify on the point of the effect of diversions at different points.

A. I could not tell the exact amount except by hearsay.

Q. Assuming that there would be a loss in the level of five inches in your district, state what effect it would have in your district at the particular points.

Mr. Williams: Objected to first on the ground it assumes a condition not shown; and in the second place that it is incompetent, irrelevant and immaterial, because this suit has nothing to do with the diversion of 10,000 cubic feet of water per second.

Mr. Reid: Q. Assume that 4,000 instead of 10,000 cubic feet, as in the other question, would lower the level of Lake Michigan two and a half inches, would that affect the level of the water in your district?

A. It would.

Mr. Williams: I object to the question on the ground it is improper; on the ground it contains an assumption; on the ground it has no meaning whatever.

Mr. Reid: Q. Assuming that the water in your district were lowered two and a half inches, would it affect the practical navigation therein?

Mr. Williams: I object to that question on the ground the witness has not shown himself to be qualified to testify upon questions of navigation.

A. It would.

Q. What effect would the loss of two and a half inches of water in your district have on the different places in your district?

A. It would have a lowering effect; while not necessarily of two and a half inches at these localities, it still would have an appreciable lowering effect at each of the localities that I have alluded to.

Q. Where would the loss of two and a half inches make any difference in your district?

A. It would make a difference in the district to all harbors on Lake Huron; not exactly to two and a half inches.

Q. What do you consider the critical points in your district for navigation?

A. The critical points for large vessels are Poe Lock and the foot of Detroit River.

Q. What effect would the loss of two and a half inches of water in the level have on these particular places?

Mr. Williams: I object to that question on the ground that it assumes the lowering of a definite amount at these particular points, and there is no testimony yet in the record—the witness testifies he can only testify as to hearsay as to the effect of a lowering of two and a half inches at Chicago on these different points; therefore I object to the question as an assumption.

A. That would require a mathematical computation to determine, as the level of Lake Erie does not fall exactly in co-ordinance with the level of Lake Huron, nor does the level below the lock at the Sault exactly co-incide with the level of Lake Huron.

Mr. Reid: Q. What effect would it have on the amount of water that would be in these particular places that you name, considering the vessels that go through them, having in mind the fact that you people give to the carriers on the lakes the depths to which they can load?

Question objected to by counsel for the defendant, on the ground it is incompetent, irrelevant, immaterial, and calls for a conclusion and not a fact; and on the ground

that it is based upon an assumption that has not been shown to exist.

A. Well, it would lower those depths.

Q. At these critical points state the fact in regard to the vessels, if it is a fact, loading right down to the very limit that you people allow them.

A. These vessels load to the limit and sometimes even beyond the limit. I have to give instructions to allow no vessel to enter the Poe Lock that draws more than the orders admit for that date.

Q. Now, if you had an inch or two inches or two inches and a half less water in those particular places, they would have to load that much lighter would they not?

A. They would load just that much lighter. If they had two inches less, that would be the—

Q. Would one inch make any difference whatever?

A. Every inch, then, they would make use of.

Q. Do you know the number of tons those big vessels load to the inch beyond a certain amount?

A. They load from 75 tons to 100 tons to the inch; that is when they are loaded; that is when you are between 18 and 19 feet, or 19 and 20.

Q. The lowering of an inch at Bar Point would have the same results?

A. The lowering at Bar Point would have practically the same results. They utilize that to the utmost limits.

Mr. Reid: That is all.

Witness: Let me state in reference to that that one time it will be the Poe Lock and another time Bar Point where we have conditions—Bar Point is lower than Poe Lock, and other conditions when Poe Lock is lower than Bar Point; but the limiting depth that we have, they will utilize to that extent.

Cross-Examination by Mr. Williams.

Q. Colonel, you speak of a vessel being loaded between 19 and 20 feet to the extent of about from 75 to 100 tons to the inch?

A. Seventy-five to 100 tons to the inch would be about what it was.

Q. Assume that a vessel is loaded to a depth of five feet, and then loaded an additional inch, would that be a different

amount that would be required to lower it an inch, after it had been loaded to 19 feet?

A. Yes, there the effect of the bottom would enter in more.

Q. Sir?

A. Yes, sir, I should say the effect would be—there is a slight curvature at the bottom. These boats are pretty nearly rectangles so that when you get down a little ways they lower about the same; but there is a slight curve to the bottom, and I think in the earlier loading, I should say that there would be a tendency to be a little less amount for—

Q. For each inch?

A. For each inch.

Q. Does that amount of loading necessary to lower the boat one inch increase proportionately all the way down from say 6 feet to 20 feet?

A. No, after you get the boat started, it is pretty nearly a rectangular section, but in the earlier starting of loading, I would not be able to say; in the first place your boat is tilted instead of being a rectangle she is a triangle; I should not know just what would take place, but after she gets well loaded then she is pretty nearly rectangular.

Q. Will you give me the name of any vessel that loads 100 tons to the inch?

A. Well, I should take one of these 605 footers, that would come very close to it. They would be the maximum.

Q. Do you know the name of any of those boats that you refer to?

A. No, I cannot at the present time recall the names of the—

Q. How many of those 605 foot boats are there navigating the Great Lakes in your district now?

A. At the present time there are none; but there are five or six.

Q. What is the depth of the water at the Poe Lock?

A. Poe Lock, the last I heard it was 18 feet 5 inches was the depth allowed in the Poe Lock.

Q. And that was the limit of depth at that time?

A. At this particular time.

Q. What is the average depth at Bar Point?

A. Well, that depends on the stage of Lake Erie, and at the average stage of Lake Erie it would be about a little over 20 feet.

Q. Now what is the average depth, taking the mean level

of the water in Lake Huron and Lake Erie, of Ballard's Reef?

A. Ballard's Reef, that is a little over—about 21 feet at mean levels.

Q. Now you state that there are improvements now in progress on the Detroit River?

A. Yes, sir.

Q. And at Bar Point?

A. There is not in progress at Bar Point, but we contemplate improving Bar Point.

Q. Plans are made for improving Bar Point?

A. For improving Bar Point.

Q. When those plans have been executed and the work contemplated is completed, will the depth of water at Bar Point be increased?

A. We intend to have that 21 feet at extreme low water.

Q. Twenty-one feet at extreme low water. What work is now being done at the Poe Lock?

A. Poe Lock, we are at the present time enlarging the channel entrance to the lock and we are proposing to build a second lock, to increase the depth there.

Q. To what extent will the depth there be increased?

A. To 24½ feet.

Q. When will that improvement be completed?

A. We expect in about five years.

Q. In five years?

A. About five years, hope to complete it.

Q. When do you contemplate, would you say, that the work on the Detroit River at Bar Point will be completed?

A. We will improve the Bar Point reach within the next year.

Q. What effect will the improvement of the Detroit River have upon the level of the Detroit River?

A. I do not know.

Q. What is the natural result of the improvement, does it increase or decrease the slope in the river?

A. It should theoretically increase the slope—decrease the slope.

Q. Decrease the slope?

A. No, let me see a minute: No, it increases the slope over the section of the river not improved.

Q. Over the section not improved?

A. Not improved; decreases it over the section improved.

Q. Will this deepening, in your opinion, provide for an

outlet of a greater amount of water than now flows through the Detroit River?

A. Yes, I think it will provide for a slight increase.

Q. And the supply of water which flows through the Detroit River comes primarily from Lakes Huron and Michigan does it not?

A. Comes from Lakes Huron and Michigan.

Q. And the effect of that improvement will be of itself theoretically at least, to lower the level of Lake Huron?

A. Theoretically, yes.

Q. What do you say practically?

A. Practically I say I don't know, as I am at the present time engaged in trying to determine just that very question.

Q. You can conceive of a situation then where theoretically the withdrawal of water and increase of flow through a channel leading from Lake Huron ought to lower the level, but actually would not?

A. No, I didn't say that. I say that theoretically I think it does but it may not be a practical question of sufficient—

Q. You would want further investigation before you would say actually it did?

A. Actually it did; that is it was of any practical amount.

Q. And the level of Lake Huron is substantially the same as the level of Lake Michigan?

A. Yes.

Q. In other words what affects the level of the water in Lake Huron, to the same degree affects the level of the water in Lake Michigan?

A. Yes.

Q. In making your reports to the commercial interests that navigate the Great Lakes, you report the navigable depths at the critical points?

A. I report particularly the navigable depths at the Sault.

Q. At the Poe Lock?

A. At the Poe Lock.

Q. And that is considered really the critical point?

A. That is at the present time the critical point.

Q. How nearly do you report, and how closely do you report that navigable depth, in inches or fractions?

A. What I report is the safe—what is considered the safe limit of loading for the boat so that she will not get aground in the lock.

Q. Do you report that in inches or in feet?

A. I don't remember whether it is reported in feet and inches, or feet and tenths.

Q. But either in feet and inches or feet and tenths?

A. Either in feet and inches or feet and tenths.

Q. How closely to the actual navigable depth do you report it safe for a vessel to load?

A. I don't know what the exact relation is there.

Q. You prepare the reports yourself?

A. I do not; I instruct my assistant at the Sault to submit these daily reports of what he considers safe for a vessel.

Q. Then the reports you have mentioned that are given to the owners of the vessels are not made or submitted by you?

A. They are submitted at the Sault.

Q. They are not submitted as the result of any specific direction of your own?

A. Except that I specifically direct them to report the safe depths.

Q. But you don't know the proportion of the depth to the safety of loading?

A. No, I do not.

Q. How do you arrive at the displacement per inch of depth in deep vessels?

A. By the area, cross section of your vessel, multiplied by the cubic feet, multiplied by a cubic foot of water.

Q. Multiplied by what?

A. By the weight of a cubic foot of water.

Q. What is the width of these 605 foot vessels?

A. A little over 60 feet.

Q. About 60 isn't it?

A. It is a little over 60.

Q. It is an easy matter to compute in a vessel 605 feet long and 60 feet wide what the displacement is?

A. I think probably 61 feet wide would be nearer the larger ones.

Q. Very well. I suppose you can do it in just a minute, figure the displacement per inch?

Mr. Reid: I object to this; this is no time for calculation, and things of this kind. The Colonel does not have to do it if he does not want to; encumber the record here with a lot of calculations.

The Witness: I should make that about 94 tons.

Mr. Williams: You figure it as a perfect rectangle.

A. I just took it as a perfect rectangle.

Q. Isn't it customary in making those figures to take 90 per cent., by reason of the slopes at the bottom?

A. It may be. I say, my expression is 75 to 100 tons.

Q. You take the net tons of 2,000 pounds instead of the gross tons, 2,240?

A. Yes.

Mr. Wilkerson: Q. How much would it be allowing 2,240 to the ton?

A. Seventy-five tons. I made the statement 75 to 100 tons.

Mr. Wilkerson: Seventy-five is good for our purpose.

Mr. Williams: Q. Are these improvements that you have testified to as being now in progress going on constantly under the direction of the government?

A. They are at the present time.

Mr. Wilkerson: And with the permission of the Secretary of War, I assume.

Mr. Williams: It is a part of the general policy of the government to adjust the condition of the harbors at the critical points to the needs of navigation along the Great Lakes, and this is in pursuance of that general policy?

A. The general policy has been to increase the depths, according to the demands of navigation.

Q. You were asked with reference to a lowering of the lake level at Chicago to the extent of two and a half inches. You do not, of your own knowledge, pretend to give an opinion as to what effect that would have upon these critical points?

A. I do not.

Q. And your answers are all based upon the presumption of two and a half inches at those points?

A. No, they are based on that there will be a reduction at those points, but the amount of that reduction, whether it will be two and a half inches or not, I do not pretend to say.

Q. The improvement of any of the connecting channels lying below Lake Huron will have a tendency, at least theoretically, to lower the levels in the lakes lying to the north?

A. Yes, I think theoretically it would.

Q. The level of Lake Superior would not be influenced by any improvement made below the locks?

A. Not by any improvement made below the falls.

Q. St. Mary's falls. These improvements of the connecting waters lying below Lake Huron have been going on a number of years?

A. Yes, sir.

Q. Have you made any observations or have you familiarized yourself with the result of those improvements?

A. Yes.

Q. Have those improvements tended to lower the level of Lakes Huron and Michigan?

A. I can't find any evidence that they have.

Q. In your opinion as an engineer would you say, without looking into the concrete evidence, whether the tendency would be in that direction?

A. Well, the tendency would be in that direction, but in a very small amount, so small an amount that it is going to be very difficult to determine it. The enlargement of the section is about 5,000 square feet through Lime Kiln Crossing.

Q. And what will be the increasing flow through an enlarged section of that extent?

A. Well, the increased flow immediately in that section will probably be in the vicinity of 14,000 cubic feet, in that particular section; that is if it was just merely that section alone that was being considered.

Q. By the improvement that you have referred to, what would be the increased flow through the St. Clair River?

A. Well, that is just what is very difficult to determine. It will have very much less effect on the St. Clair River than it would on the Detroit River; and it is going to have a comparatively small effect on the Detroit River, because this section is a very short section in a long length of river, and the small change in slope at this one point has got to be spread over the entire river; to make a very serious change.

Re-direct Examination by Mr. Reid.

Q. These measurements at the Poe Lock are made in your department, under your direction are they not?

A. There are no measurments at the Poe—what do you mean, of the depth at the Poe Lock?

Q. Yes.

A. Yes, they are made by my assistants at the Lock.

Mr. Reid: I think that is all.

Mr. Wilkerson: Q. I want to ask you a further question about this Livingston cut: Do I understand that it is proposed to compensate the increased cut at one place, by filling in at another? What is the fact about that?

A. I don't remember having testified anything about the Livingston cut.

Mr. Williams: We have not heard about the Livingston cut before.

Mr. Wilkerson: We understood you were referring to the Livingston cut.

Mr. Reid: What section was that you were referring to?

A. I was referring to the existing section that has been increased; the existing Lime Kiln Crossing extending about 5,000 square feet, but I can find no evidence of its having lowered either Lake St. Clair or Lake Michigan.

Mr. Wilkerson: Q. Has there been any filling in there?

A. We recently built a coffer dam that has filled in very much more than we have excavated.

Q. So that in a sense it would compensate what is taken out in the other way?

A. That will more than compensate for all we have taken out.

Q. In the course of cross-examination, in response to some questions as to the effect of these improvements upon the level of the lakes, you said that theoretically it would have some effect. By that do you mean that if you go ahead and do what you propose to do and the loss would remain constant, that will be the result?

Mr. Williams: I object to the question as a statement by counsel of what the witness means; and I prefer to have the witness state what he means.

Mr. Wilkerson: Q. That is what you mean?

A. I said theoretically it might lower, but that practically I had not seen any effect of its lowering.

Q. Well, what do you mean by theoretically?

A. Well, there are certain results of theory that are obscured by the general things we see in nature. You can say theoretically a thing will be done, and you will find practically that the differences are so slight that they are obscured, and that practically you do not see any effect from it, that is what I mean.

Q. What is it that limits the size of vessels that can be used on the lakes?

A. The draft.

Q. And what is there in connection with either these channels about which you have been testifying, or with reference to harbors about which you have been testifying, which make

it impossible, if that is the fact, to use on Lake Michigan and Lake Huron an Ocean steamer?

Mr. Williams: I object to the question on the ground it is immaterial, and on the ground that it assumes a condition.

Mr. Wilkerson: I do not make myself clear. I want to find out what relation the depth of these channels and the harbors has to the size of the vessels that can be used?

A. Why, they are simply building vessels just as large as we have channels for them.

Q. And are these vessels much larger or much smaller than the vessels which are used, for instance, on the ocean?

A. They are very much smaller. A great many vessels on the ocean are very much larger. A great many other vessels on the ocean are smaller.

Q. I mean as compared with the largest vessels that are used?

A. The largest vessels on the ocean are very much larger than the largest vessels on the lake.

Q. What would be necessary to do to use large ocean vessels on Lake Huron?

A. If you were going to build as deep steamers on the lakes as you have on the ocean, we would have to have channels 35 feet deep.

Q. You would have to deepen these channels and deepen the harbors?

A. Deepen the harbors.

Q. To follow that up, along the line of cross-examination, what practical relation does the size of vessels it is possible to use on the lakes bear to the lowering of these channels and these harbors, even by so small an amount as an inch?

A. If you lower your channel an inch—

Mr. Williams: I want to interpose an objection to the question as calling for a conclusion instead of for facts, on which the court can form its own conclusions.

Mr. Wilkerson: Answer the question.

A. If you lower your channel one inch, you diminish by just that amount the draft which you can utilize in your channel.

Q. And would you say that that same observation would apply to harbors?

A. It would apply to any channel.

Re-cross Examination by Mr. Williams.

Q. That would not hold true however, where the depth of the channel was considerably greater than the draft of the vessel?

A. No, sir. That would only apply to the limiting points of the channel.

Q. The lowering of Lakes Huron and Michigan, you have already testified, would not have any effect upon the amount of water, the depth of the water in the Poe Lock?

A. No, I have not made any such statement as that; I never intended to. The lowering of the water of Lake Michigan will have a very decided effect on the Poe Lock.

Q. What will be the effect on the Poe Lock in the amount of water—

A. It will be in proportion to the lowering of Lake Michigan, but as to the exact amount I could not tell you without a mathematical computation.

Q. Would it be as much as in Lake Michigan?

A. Not quite as much, but it will bear relation to Lake Michigan. That would be a mathematical computation that I have not made.

Q. You have testified that at the Lime Kiln Crossing, when the improvement was being made there, there was a coffer dam built?

A. No, not in the Lime Kiln Crossing, but there is a coffer dam being built on the work we are now constructing.

Q. Did you testify that when the cross section was increased 5,000 square feet that the filling was deposited against it?

A. No—well, that filling was deposited in a sort of a way to compensate in the channel which we are now improving, under the name of the Livingston channel.

Q. And that filling is in the shallow water?

A. That was placed in the shallow water.

Q. Would that have as great an effect on the amount of water flowing through the channel as though it were deposited in the channel proper?

A. No, it would be not as much.

Q. Would you say, Colonel, that the average of the size of vessels navigating the Great Lakes was less than the average size of the vessels navigating the ocean?

A. No, it is very much larger, the average; but the great

vessel that navigates the ocean is very much larger than the greatest vessel that navigates the Great Lakes.

Mr. Wilkerson: That is for the reason you stated.

Witness: The average vessel is a very different thing from the largest vessel.

April 19, 1909; 2:00 p. m.

Court convened pursuant to recess.

Present: As before.

EBEN S. WHEELER, a witness called on behalf of the complainant, was first duly cautioned and sworn, and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name, please?
A. Eben S. Wheeler.
Q. Where do you live?
A. In Detroit, Michigan.
Q. What is your present occupation or profession?
A. Civil engineer; United States Assistant Civil Engineer.
Q. In what line of service?
A. I am in the river and harbor improvement office.
Q. At Detroit?
A. At Detroit.
Q. How long have you been connected with that office?
A. That particular office about ten years.

Q. I want to bring out, Mr. Wheeler, your experience as an engineer. Where were you educated?

A. At the University of Michigan. I received the degree of Civil Engineer in '67, and an honorary degree in '97.

Q. Commencing at the time you received your degree of civil engineer, in a general way, and yet being specific as to particular large pieces of work with which you have been connected, I will ask you to state your experience.

A. Well, I was employed by the United States Government on the United States Lake Survey for a number of years, during which time I was engaged in many of the surveys.

Q. What were some of the more important ones?

A. The triangulation of the Great Lakes. I planned most of that and measured its base lines and determined its standards of measurement, and I was also connected with the sur-

veys of various harbors and parts of the shores of Lake Superior. I assisted in some of the earlier stream measurements in the Detroit and St. Clair Rivers, and in the reduction of the same. After I was transferred from the lake survey to the river and harbor office I first went to the Sault, and had charge of the works at Sault Ste. Marie and the superintending of the building of the whole lock under General Poe, I was in local charge. Later I was chief engineer of the Nicaraguan Canal Commission of 1898-9, and since then have been engaged in various works in the river and harbor improvement. While at the Sault I had charge of the stream measurements of the St. Marys River.

Q. In addition to what you have stated is there anything that you can add with reference to your connection with hydraulic measurements of the Great Lakes, tending to give you experience in matters of that kind?

A. I do not know that there is anything further.

Q. You have stated the principal facts—

A. Yes.

Q. —upon which your experience is based. Well, can you state a little more definitely with reference to studies which you may have made of water measurements and determining lake levels, computations with which you have had to do?

A. I discussed the river system of Nicaragua and published the results in the report of the Commission. I have discussed the physics of the Great Lakes, which has appeared from time to time in the chief engineer's reports. I made rather an extensive report of that kind in the report of 1893, and I have made some study in regard to the relative elevations of the different lakes.

Q. You say you made a study of the physics of the Great Lakes; a little more concretely, just what do you mean by that?

A. That includes a study of climatic effects on the lakes, and the relation of the lakes to each other, the characteristics of the drainage basins of the various lakes and it involves a study and analysis of any of the peculiar fluctuations which take place in the levels of the lakes in regard to each other, involves something of the study of the winds and precipitation, humidity, evaporation and allied studies.

Q. You used the term, relation of the lakes to each other. Just what particular relations had you in mind in using that term?

A. One of the most important is the elevation of their surfaces.

Q. And just how much of a study did you make of that, over how long a period of time did your observations extend, and how completely did you discuss that study with the different boards with which you conferred?

A. I occupied several month, perhaps more than half a year, in that special subject. I cannot say that it is very completely discussed yet.

Q. With respect now to the navigation of the Great Lakes, during how long a period have you been making a study of the subject, and having connection with that?

A. Why, since about 1882, when I went to Sault Ste. Marie that became necessary in the building of the lock, and I have a knowledge of the navigation of the lakes, its needs and necessities.

Q. And since the time you commenced that line of work, how continuous has been your observation and study of matters connected with that subject as carried on?

A. I cannot say that it is complete, but I have had the subject generally in mind and have treated it in a general way, hardly exhausted it yet, though—it is a pretty large subject.

Q. Well, compared with others in your line of work who have been studying this subject, what do you say as to the amount of time you have spent, speaking in a comparative way?

A. Well, I should say I have spent more time than most people have on the subject. I do not know that I have got better results, though.

Q. Now, you referred, in enumerating the subjects of which you had made a study, to the term "relative elevation of the lakes" and the "relative elevations of the lake," for the benefit of those of us whom may not be so familiar with the phraseology of this subject, will you define a little more exactly what you mean by that term?

A. Beginning with Lake Superior we find it in general is about 20 feet higher than Lakes Huron and Michigan, but this is not a constant, this varies. The same is true between Lake Huron and Lake Erie. In general that is about eight and one-half feet, the difference between the two lakes. There have been times when it has been more than 10 and sometimes when it has been less than six. We come to Lake Erie and Ontario, and the same variation in elevation is discovered there, and the

causes which lead to these changes in elevation are complex and require some analysis and study to determine them. Perhaps they are not all well determined yet.

Q. What do you mean by the word "elevation" as used in speaking of the lake, the elevation of the lake?

A. Its elevation above sea level, which has been carefully determined at the several lakes.

Q. That means the surface of the lake is so many feet—

A. Above the surface of the sea.

Q. Above the surface of the sea?

A. There would be two planes, that is imaginary plane, the plane of the lake as extended over the ocean, and the two places would be separated by a certain distance.

Q. And that distance you speak of as the elevation of the lake?

A. That is the elevation of the lakes.

Q. Speaking of the elevation of the lake, what is the relation between Lake Michigan and Lake Huron?

A. They are the same. As far as elevation is concerned, they are one, the two make one body of water, one lake. The separation is only for geographical convenience, the separation in name. This would also include Georgian Bay, and those regions on the North of Lake Huron.

Q. In the light of your observations and study, Mr. Wheeler, what do you say would be the effect of the diversion of a given quantity of water, as for example, 4,000 cubic feet per second at Chicago, upon Lake Michigan, upon the elevation of Lake Michigan?

A. One of the results of such a diversion would be ultimately to diminish the flow in the St. Clair River an equal amount. A second result would be to lower the level of Lakes Huron and Michigan, and also of Erie and Ontario, and the connecting rivers.

Q. With reference to the effect of the diversion of this quantity of water, with reference to the determination of the amount of this lowering, have you had occasion recently to make any special inquiry into the subject, any special study of the subject?

A. I have made an examination of some of the points bearing on this question.

Q. With a view to testifying in this case as to the effect of that diversion?

A. Yes, with the purpose of giving more accurate answers than I could from memory.

Q. Supposing that something is done, as for example a diversion of this water at Chicago, the effect of which is to reduce the elevation of the lake at a given point off the shore, say, ten miles, what do you say as to the lowering at that particular point, in its relation to the lowering which would take place at other points in Lake Michigan and Lake Huron and in the harbors and channels?

A. It would lower both lakes an equal amount, both at the upper and lower extremities eventually, of both lakes.

Q. Just what do you mean by the word "lowering" as you used it in this connection?

A. Perhaps I had better refer to my notes.

Q. You may do that.

Mr. Williams: Let the record show that the witness is referring to his notes.

Mr. Wilkerson: I will ask the witness to refer to the notes to refresh his recollection, and to enable him to make a more definite answer.

A. I have said in my notes that lowering means that a definite amount of diversion at Chicago will make the surfaces of Lakes Huron and Michigan a definite amount lower at all times and places than it would have been if the diversion had not taken place. Perhaps I have given too long an answer, the actual elevation of the surfaces of the lakes at any time is the algebraic sum of all the causes which tend to change the elevations. Some of the most important of these causes are rain fall, outflow, evaporation, et cetera. If two causes, producing opposite effects, are operating at the same time then the actual effect produced will be of the same kind as the larger one, and the amount will be the difference between the two causes. For example, a merchant deposits a thousand dollars each week, and checks out fifty dollars each day, his balance is lowered by the amount he takes out, and raised by the amount he deposits, and in this case the deposits are larger than the withdrawals, therefore his balance will be raised by the difference between the two. At the end of the week it will be raised $650, notwithstanding it was lowered $350 by his withdrawals. Similarly, if for the period, we will say, from 1900 to 1908, the rain fall was greater than the outflow, and evaporation, the lake would rise. This appears to have been the case, notwithstanding the outflow for the period was increased by the diversion at Chicago. A cause which tends to lower the lake itself actually does make the lake lower than it

would have been without the cause. I do not know but my answers are a little too long.

Q. That is the sense in which you speak of the lowering of the lake level, you use the word "lower"—

A. Yes.

Q. You mean that it is lower than it would have been if that particular cause had not been present?

A. Yes, I should emphasize that, *it is lower than it would have been without the cause.*

Q. But as you have stated there through the operation of other causes the ultimate effect may be that the elevation is actually higher?

A. Yes.

Q. But through the operation of one cause the real effect of that particular cause has been to lower the level?

A. Yes.

Q. That is to say, to repeat, when you speak of "lower," you do not mean with respect to a fixed mark, but you mean with respect to the level the lake would have been in the absence of the cause?

A. Yes.

Q. Now, directing your attention again to the outflow in the St. Clair River, what is the effect of this diversion, the proposed diversion at Chicago, upon the quantity of water which would flow out through the St. Clair River?

A. It will diminish the flow ultimately in the St. Clair River an equal amount.

Q. If I may put the question in this leading way: by that you mean that ultimately there will be, if there are 4,000 cubic feet per second diverted at Chicago, that number of cubic feet per second less flowing through the St. Clair River than there would have been if the diversion had not taken place at Chicago—am I correct in that?

A. That is correct.

Q. Do you use the term "net supply" in connection with the quantity of water in the lakes?

A. Yes.

Q. What do you mean by that?

A. I am almost afraid to say, because I shall differ with Mr. Noble, and the man who differs with him is usually wrong. I have said here, net supply is all the water that flows into the lake from streams, springs, seepage, et cetera, plus all rain and snow which falls on the surface of the lake, and

minus evaporation from the lake surface and it is a concrete quantity.

Q. You say it is a concrete quantity?

A. It is a concrete quantity.

Q. Will you explain a little more fully what you mean by that?

A. Why, I don't hardly know; the lexicon would do it a great deal better.

Q. I mean by way of illustration or example.

A. Well, it is a quantity that can be measured, it is a real, an actual quantity, with suitable observation we could measure all these effects and get the net supply, and then we would know that that supply had actually been received by the lakes.

Q. What do you mean by suitable observations?

A. It would be necessary to measure the rain fall, all kinds of precipitation and evaporation, measure all of these quantities which I have mentioned here, accurately, and we would eventually get the net supply, if our observations were correct, if they were properly made.

Q. Do you happen to have any knowledge on the subject of the observations which may have been made along those lines?

A. Why, concerning precipitation continuous observations have been made by the weather bureau for about, less than thirty years. They have measured also various other quantities such as the wind, temperature, humidity and rain fall. From these observations the total amount of precipitation has been determined approximately, of course, the determination is no better than the observation, and the amount of discharge from the lake has been measured at the same time, and the difference between these two has been assumed to be the evaporation. It has been determined in that way and to that extent. That would be the total evaporation for a basin.

Q. Now, referring to items of rain fall, evaporation, absorption, the run-off in the drainage basin of the lakes, and the inflow from the St. Marys River, would the diversion of this quantity of water at Chicago have any effect upon any one of those items?

A. None at all.

Q. In other words, if I gather the result of what you have said, this diversion of water at Chicago is a fixed factor, which will tend, to the extent to which it is operated, to modify whatever condition with reference to elevation that the lake would be in, if that factor had not been produced?

A. Yes. In my answer to the previous question I said that it had no effect whatever on evaporation, precipitation and run-off. I should qualify that by stating that it has an effect on the run-off, not on its total amount, but on its locality; it changes a portion of the run-off from the St. Mary's River to Chicago. It does not change the amount; simply a change in locality. The other items are not affected at all by it, and the run-off is not affected in amount by it either.

Q. I understood you to say that would be eventually the effect that the amount of run-off through the St. Clair River would be decreased by the amount which was diverted at Chicago?

A. Yes.

Q. When you said "St. Marys River" you meant St. Clair?

A. I meant the St. Clair River; it would be ultimately decreased by that amount.

Q. Now, if the net supply were to remain absolutely the same then what would be the effect with reference to the actual elevation of the lake, as a result of this diversion at Chicago?

A. The actual elevation would begin to diminish the moment the diversion at Chicago began, and the elevation of the lake would slowly be lowered, but on account of the large area it takes some time to accomplish the thing, and it takes an infinite time to completely accomplish it.

Q. Well, how long, to substantially accomplish it?

A. In about four years a little more than 90 per cent., a little more than nine-tenths would occur.

Q. How long before half of the effect?

A. A year and a half or something like that, less than two years.

Q. How long would it be before you could say there would be an appreciable lowering?

A. Well, I haven't worked that out; I would have to express that approximately.

Q. Well, approximately?

A. If in four years it reduces the elevation four inches, that would be an average rate of an inch per year. For the first year that would be considerably more than the average rate, so I should expect there would be an inch and a half the first year—something like that—so in the first six months there would probably be three-quarters of an inch.

Q. That is, expressed by one of these formulas of a curve always approaching its limit, and never quite gets there, is that it?

A. Yes, the curve would be an asymptote to it.

Q. I am showing you, Mr. Wheeler, a chart or plat in which certain observations have been platted, of lake heights, platted as ordinates and the discharge as abscissa—that is to say, the lake heights have been so platted that they are represented by vertical lines, and the volume of discharge so they are represented by the horizontal lines, and that chart has been marked Complainant's Exhibit 1, under date, February 15, 1909. On that plat there has been a certain line drawn, expressive of the relation between the lake height and the volume of discharge, the result of which has been the determination of the loss of outflow in the St. Clair River, by reason of the diversion of water at some other point along the lakes. Have you had a copy of that plat presented to you for your consideration? (Handing plat to witness.)

A. Yes, I have had a blue print of this drawing.

Q. Now, Mr. Wheeler, this is a law suit, and one of the questions that is here for determination is, what will be the effect upon the lake elevations of Lakes Huron and Michigan as a result of this diversion of water and the corresponding loss of outflow in the St. Clair River, to which you have testified. Here are the observations and here is a line which has been drawn so as to present a basis for that computation. I wish you would take that up and, as an expert, explain first what you have to say with reference to the drawing of that line and next, what that line shows on the plat with reference to the lowering of the lake level, why you show that, take it up and explain it in your own way.

A. Well, I have examined the data and I find it to correspond with the published data from the Lake Survey Office. I have made a special study of the position of this line which is really the mean line.

Q. If I may interrupt you there just a moment, so that we may get it in the record here, are you able now to give us the references to these reports to which you have just referred, which show that those observations, as platted, are correct?

A. I think I can, I think they are before you on that paper, which you have.

Q. The one that I have?

A. Yes, the first pages.

Q. Now, let me hand this to you, and in your testimony, Mr. Wheeler, where you refer to reports, official records of any kind, it will be helpful if you will indicate so we will have

them here in the record, just to what books you have made reference, so we may be able to find the references easily.

A. I will, wherever I recollect it, and can make the reference.

Q. Yes. We will be obliged to you if you will.

A. I don't remember—shall I read this to you, or just submit—

Q. No, just read them so the Commissioner will get them in the record.

A. Well, concerning the water level tables I find those in the full reports of the Chief of Engineers for 1900, on page 5362, and for 1902, on page 2819, for 1903, page 2837. 1903 again, page 2855—1904, page 4069.

Q. You have given all the references that relate to the data on the plat which you have before you?

A. Yes.

Q. Now, go ahead with your answer with reference to that plat.

A. I have made special computation of this mean line, and I find the position of it practically the same as given here, in some of the sheets almost exactly the same. Let's see, this is the St. Clair River.

Q. Well, referring to your own computation and refreshing your recollection with reference to the plat, what have you to say as to the substantial accuracy of the line that is there drawn?

A. It is almost exactly as I find it, the differences on the plat are hardly perceptible to the eye. I will submit them here. I have drawn in red on this blue print the position of the mean line as I determined it.

Q. Did you make any attempt to determine the degree of precision of the computation?

A. Why, yes, I determined the probable error, I think I have it in my notes, that is one of the things that one don't remember. The diagonal lines on these plates show the exact mean of the observations. This is exact, it is not an estimate, it is susceptible of computation. The agreement of the observations among themselves show the probable error of the increment which really means the position of the line, as determined for the several rivers, as follows: For this one, the St. Clair, it is 227 seconds feet.

Mr. Williams: That means cubic feet per second?

A. Yes, cubic feet per second. It is the probable error of this determination of the increment.

Mr. Wilkerson: How nearly accurate would that be when expressed in simpler and easier words, if you can express it, would you call that a very high degree of precision?

A. Yes, I do.

Q. About what percentage would it be?

A. I have said in my answer that the agreement of the observations among themselves show the probable error, and I consider the small size of this probable error in evidence of the high degree of accuracy in the observations.

Q. Have you, in your own mind, figured out just the percentage of error?

A. Yes, sir; it is——

Q. Its relation?

A. The increment as determined is 25,200 s-f., and the probable error is 227, which would be a little less than 1 per cent.

Q. One-tenth of one——

A. One per cent—it is a little less than 1 per cent.

Q. Now, let us come back to this plat, Mr. Wheeler, and having gone over the questions that relate to its accuracy——

A. Well, perhaps I have not stated all that I might say——

Q. Please state what you have to say then.

A. ——on the matter of accuracy. These observations have been made for determining, what in this trial has been called the increment, we commonly use that term, which simply means the discharge due to one foot of elevation. These results show a close agreement among themselves and great care and accuracy in the observations; but the observations were made mostly in the summer season, entirely in the summer season. They may be different in the winter, they may be different on other occasions, so that the absolute value of that increment cannot be as closely known as indicated. Do I make it plain? The probable error which I give is the probable error of these observations. These observations are not sufficiently prolonged to say that the determination which is sought from them is known with entire accuracy the increment yet may be different at different times, but at the times these observations were made I know——

Q. You know that the basis of the observations, as made and platted on the plat——

A. At that time, when they were made, we know the value of the increment within this limit that I have given.

Q. Now, is there anything further that you would add in

connection with the accuracy of the computation, or have you covered that?

A. I think I have covered it. I have had this line determined, and I have checked the computation myself, and I feel perfectly safe in saying that this red line is the mean line of these observations. It is not an estimate, it is the mean line.

Q. Now, having said that with reference to the accuracy of the computation, I wish you would pick up that plat and explain to us just what it shows as the results of the determination of that line, translate it, so to speak, now, from the phraseology of the plat, to language that the layman can understand.

A. In making an observation to determine the "increment" of discharge, two things are observed, first, the elevation of the Lake surface as shown on the gage. Second, the amount in cubic feet per second of the discharge. Suppose at the time of the first observation the elevation of the lake surface to be 580 feet and the discharge to be 174,200 s-f. Suppose that at the time of the second observation the elevation of the water surface is found to be 581 feet and the discharge 199,400 seconds feet. These two observations together show that the elevation of the lake surface increased one foot and that the discharge increased 25,200 seconds feet. This is the "increment" or the change in discharge corresponding to one foot change in elevation. To show this result graphically the observations are plotted on the sheet as follows,—For the first one a circle is made around the point where the horizontal line representing 580 feet of elevation crosses the vertical line representing 174,200 seconds feet of discharge, and similarly for the second observation, a circle is drawn around the point where the horizontal line representing 581 feet of elevation crosses the vertical line representing 199,400 seconds feet of discharge. If now a diagonal line should be drawn through the two points one could tell by inspection what elevation of surface would correspond to any discharge. The diagonal on the plat is such a line, but instead of being made from two observations only, it is the mean of many observations, made in different years at different elevations. Since a change of discharge of 25,200 seconds feet, causes a change in surface elevation of one foot or 12 inches, it follows that a change in discharge of 1 second foot would cause a change in surface elevation of 0.000476 inch. For the purposes of this case this is a more convenient form for expressing the "increment" of discharge, because the change in surface elevation caused by

any change in discharge or "diversion" can be found by simply multiplying the diversion, when expressed in seconds feet by 0.000476, which gives, in inches, the resulting change in elevation.

Q. Well, now, having drawn the line, what is the result of that plat as to determining the effect upon the level of Lake Huron resulting from this loss of outflow through the St. Clair River?

A. We find that the value of the change for one foot is 25,-200 seconds feet, that is, we find that if the discharge is diminished 25,200 seconds feet, that the elevation will be diminished one foot.

Q. Now, then, referring to the scale that is at the side of this plat here, at the head "Reduction in outflow, cubic feet seconds" and the other "Loss in stage, inches," what do you get there as to the—well, on the basis of your computation 10,000 cubic feet diversion, with the corresponding loss of outflow in the St. Clair River, would result in how much of a loss in stage of the lake?

A. It would come from there (indicating) down to there (indicating as shown graphically).

Q. That would be five inches?

A. If 14,000 it would come down to here, seven inches.

Q. Seven inches?

A. Yes, sir; on the natural scale.

Q. In your computation in which you went over these figures yourself, I notice there is a slight difference in the figure which you use in the formula that is down here on the original plat as denominator, a slight difference in figures in the computation. Does that make any substantial difference?

A. It does not make any substantial difference.

Q. In the result?

A. None at all, or hardly any. Hardly any appreciable result.

Q. That is, they are so nearly together that when you come to express the result in lake elevation in inches there is no appreciable——

A. No appreciable difference. I of course stand by my own computations.

Q. Yes.

A. I had them made with great care by an assistant, and I checked them myself, and I have great confidence in their correctness.

Q. Now, then, having explained to us the method through

which this result is obtained, and putting to you as an expert the question as to your conclusion, what, Mr. Wheeler, would be the effect upon the level of Lakes Huron and Michigan of the diversion of 10,000 cubic feet with the corresponding loss of outflow through the St. Clair River in inches?

A. I think I have computed that. You ask for that in inches, and I had the result in feet. I will have to figure it in inches.

Q. Give it to us in feet the way you have it. You may give the result in inches if you will—you say you have the computation in feet—our computations are all——

A. I can make it in inches in a moment.

Q. Very well, then, that would probably be more convenient, because we have been using that result.

A. Four inches and seventy-six thousandths for 10,000 seconds feet.

Q. Have you made the result for a diversion of 4,000 cubic feet at Chicago, with the corresponding loss of outflow from the St. Clair River?

A. It would be one and nine-tenths inches.

Q. That would be at the same rate for——

A. This is the same rate, yes.

Q. It would be at the same rate for any different quantity of water diversion?

A. Yes, sir.

Q. That is to say, it would be in the same proportion for one or two or five or eight thousand cubic feet?

A. True, with this limitation: This is true for any range of level that we know anything about, that we have ever had a chance to observe. It would not be true in an infinite range of level; there would come a time when your range would be distributed, but for anything we have, any range of level we have had this is true.

Q. In giving your result for the diversion of 4,000 feet, have you given that in tenths or in inches—will you look at it again?

A. It is 16/100 of a foot; and for 1,000 feet it would be one-fourth that much; I make it 48/100 inch.

Q. What is it for 4,000?

A. Oh, I made an error in this computation.

Q. I think it is a little over two inches when you come to figure it out. It would be one and nine-tenths inches.

Q. A fraction under two inches?

A. Yes.

Q. A small fraction under two inches. Now then the result of that is that speaking with substantial accuracy the effect of the division of each 1,000 cubic feet per second is, within the limits that there have been any opportunity to observe, a reduction of about half an inch in lake elevation.

A. Half an inch.

Q. Half an inch for each 1,000 feet?

A. Half an inch for each 1,000 feet.

Q. What will be the effect of this lowering on the water in the St. Mary's River at the foot of the locks?

A. That requires rather a long answer.

Mr. Williams: What condition do you mean now, a diversion of 4,000 or 10,000 or 5,000?

Mr. Wilkerson: For any diversion.

A. You mean the percentage.

Q. I mean the percentage of diversion.

A. During the 17 years between 1891 and 1907 there were no large changes in the channel of the St. Mary's River, I mean by that there were no dredgings of any considerable extent done there to affect the current. The slope between the locks and Mud Lake remained nearly uniform, the mean being 2.12 of a foot, that is the water at the foot of the locks was 2.12 higher than in Mud Lake. The observations for those 17 years show that any change in the surface elevation of Lake Huron caused a change in the surface elevation at the foot of the Locks amounting to 58 per cent. of the Huron change. In 1907, the West Neebish Channel was opened. This reduced the slope in the river, the amount is not yet very accurately known. The mean slope for 1908 was one foot and twenty-two hundredths. This decrease of slope would tend to increase the percentage of change, probably proportionally. If so, it would now be about 75 per cent of the Huron change. That is the answer that you wanted, I believe.

Q. Now, with reference to the percentage at the critical points of the St. Mary's River, what are those critical points and what would be the effect of the lowering of the level of the lakes at those points?

A. The critical points in the river are Sailors Encampment, Middle and West Neebish and Little Rapids, and the locks. The percentage of change for Mud Lake being 100 and for the locks as just determined, 75 per cent., the intermediate point would be between 100 and 75. I estimate Sailors Encampment at 98 per cent.; Middle and West Neebish, 90 per cent., and Little Rapids, 80 per cent. This is an estimate that

is made from the geographical position of the points. We have no observation at those points, it is only an estimate.

Q. What would be the effect of the diversion of a certain quantity of water from Lake Michigan at Chicago ultimately upon the outflow of the Niagara and St. Lawrence Rivers?

A. I have not made those computations and could not give them with any great accuracy.

Q. Can you give any——

A. As far as amount is concerned it would be the same, as far as the lowering is concerned——

Q. I was speaking—I think perhaps I did not speak distinctly. I was asking simply as to the amount of loss.

A. Oh, it is the same for those, too.

Q. That is to say, if there is a loss of outflow through the St. Clair River there will ultimately be the same loss in outflow through the Niagara and St. Lawrence Rivers?

A. Yes.

Q. Is that correct?

A. That is correct.

Q. I direct your attention, Mr. Wheeler, to two plats or charts which have been marked in this case Complainant's Exhibits Numbers 3 and 4, respectively, under date of February 15, 1909. Those plats or charts purport to show computations with reference to the loss of level in Lake Erie corresponding to the loss of outflow in the Niagara River by reason of the diversion of a certain quantity of water from Lake Michigan at Chicago. Have you seen those charts before?

A. I have.

Q. Well, what did you do in connection with those?

A. I computed the mean line drawn on the plat.

Q. Did you verify the accuracy of the observations by referring to any——

A. I referred to the published reports and verified them in that way.

Q. Can you tell us to what you referred?

A. It is the same references as before.

Q. The same references as before?

A. Yes.

Q. Now, take up those two plats and follow in the same method of explanation which you followed in connection with the plat concerning the loss of outflow through the St. Clair River, and explain to us what the result of those computations is.

A. The observations as platted, were platted in precisely, a

similar manner, to the one for the St. Clair River. Perhaps it would not be necessary to repeat that, would it?

Q. You can condense that—that is to say, if you followed the same general method, you can say it was the same general method you followed in the other computation.

A. The mean line was computed in the same manner as for the St. Clair River. The determinations are almost exactly coincident with those which were given me on the plat.

Q. If you will pardon me, I want to see, I think the record shows it, but I want to be sure—you verified by the published reports the accuracy of the points as platted?

A. Yes.

Q. And those you have recomputed yourself?

A. Yes.

Q. The diagonal lines?

A. Yes, that is the mean line, the mean of those observations.

Q. Now, then, go ahead with your answer.

A. I find that they correspond almost exactly with those which I found on the sheet. The discharge is for two different sections of the Niagara River; one section gives the increment 21,867 seconds feet; the other section gives it 21,744 seconds feet. The probable error of these, of the first of these, is 157 seconds feet, and of the other it is 143 seconds feet, and as before, the very small probable error is to me an indication of the excellence of the observations and the agreement of the two sections of the river is a still further indication of the excellence and accuracy of the observations.

Q. Now what is the result of that computation in the showing of the relation between the reduction in the outflow, and the loss in the stage of the Lake in inches, as shown by the scale that appears on the plat, have you that computed in feet as you had in the case of——

A. No, I haven't.

Q. ——of Huron. I mean of the——

A. Of the St. Clair discharge?

Q. The St. Clair discharge, yes.

A. I can give that in inches in a short time. For the Niagara River the diversion of 1,000 seconds feet would lower the lake 55/100 of an inch and any other amount in proportion.

Q. Ten thousand would be about 5½ inches, and 4,000 would be about two and two-tenths of an inch?

A. Four thousand would be four times as much as that—well, 2.2 of an inch 4,000 would be.

Recess to April 20, 1909, at 10:30 a. m.

April 20, 1909, 10:30 o'clock, a. m.

Parties met pursuant to adjournment.

EBEN S. WHEELER resumed the stand for further examination by Mr. Wilkerson, on behalf of the Government, and testified as follows:

Q. Directing your attention again, Mr. Wheeler, to the lowering of Lake Huron and Michigan, if they be lowered a certain known amount, and Lake Erie a certain known amount, what would be the lowering in the Detroit River and Lake St. Clair and the St. Clair River, speaking particularly with reference to the critical places in that chain?

A. Well, reading from my notes, observations from 1884 to 1909, of the U. S. Lake Survey—do you wish a reference to that?

Q. Yes, if you can give it to us.

A. They will be found in the reports of the Chief of Engineers from 1900 to 1904. These observations show that a lowering of Lake Huron lowers St. Clair 22 per cent. of the Huron change; a lowering of Lake Erie lowers Lake St. Clair 63 per cent. of the Erie change. If Erie and Huron are lowered an equal amount simultaneously, St. Clair will be lowered 85 per cent.

Q. How did you get that result?

A. That comes from direct observations. The Deep Water Commission—I have forgotten what date—placed observers all along the river from Port Huron to Gibraltar, reading the elevations of many places. They waited until there was a change of about seven-tenths of a foot in both lakes, and read it again. These curves show that while there was a change of seven-tenths at the extremities, there was only about eighty-five one-hundredths in Lake St. Clair, and perhaps fifty-three one-hundredths in the narrowest and rapidest place, which was opposite Algonac. This result is derived from a range of four and a half feet in Huron and three and a half feet in Erie. A similar result is shown by the observations made by the Board of Engineers on Deep Waterways in 1898 and 1899. That is what I have just alluded to.

Q. What have you to say about the probable error in those results, based upon the observations?

A. The agreement of the observations among themselves indicates that the probable error of these results is 8 per cent.; that is, if the lowering of Huron and Erie be given, the lowering of the St. Clair can be found by means of these percentages within 8 per cent.

Q. What do you say about the observations given by the Board on Deep Waterways, as the result of their observations?

A. The observations made by the Board on Deep Waterways in 1898 and 1899 show that if Huron and Erie are lowered an equal amount, St. Clair and Detroit Rivers will be lowered respectively 75 and 91 per cent. of this amount.

Q. What are the critical places between Erie and Huron?

A. The critical places, beginning at the lower end, is first Amherstberg.

Q. What about the percentage there?

A. About 95 per cent.

Q. Of what?

A. Of the lowering in Lake Erie.

Q. What is the next one?

A. Lake St. Clair.

Q. And the per cent. there?

A. That would be about 85 per cent.

Q. The next one?

A. Squirrel Island.

Q. And the per cent. there?

A. About 66 per cent.

Q. And the next?

A. Opposite the village of St. Clair.

Q. And the per cent?

A. 83 per cent.

Q. The next one?

A. Stag Island.

Q. And the per cent.?

A. The same, 83 per cent.

Q. The next one?

A. Opposite Black River, 88 per cent.

Q. The next one?

A. And last in the lower end of Lake Huron, for a distance of four miles, it would be 100 per cent. Now these percentages are determined from the geographical position of these

critical points. We have not observations made at all these points; and they are therefore approximate.

Q. I show you another one of these charts, Mr. Wheeler, that have been marked Complainant's Exhibit No. 2, date February 16, 1909, and ask you to state whether you have seen that before, and what you have done with reference to it?

A. This has been given to me and I have examined the observations, so as to note that they correspond with the published observations of the Lake Survey; and I have computed the diagonal line, or the mean line, recomputed; find it to agree almost exactly with the given one here. On the blue print which I submitted, the line which I computed is shown in red, which corresponds almost exactly with this one. This line shows graphically the discharge which corresponds to a change in stage. It is found that the discharge for one foot of level is equal to 28,870 cubic feet per second. That is the St. Lawrence River.

Q. What would be the lowering effect, therefore, of the diversion at Chicago of 4,000 cubic feet of water per second upon the level of the St. Lawrence River?

A. Since this shows that a diversion of 28,870 cubic feet would lower it one foot, 4,000 feet would be its proportional part. I have not worked that out.

Q. Is the scale that is on the left hand side of the chart substantially correct as expressing the lowering effect of the diversion of this water?

A. Yes, it is correct, and it is marked on the scale here. Ten thousand cubic feet per second would——

Q. A little over four inches?

A. About four and a third inches.

Q. What is the season of navigation in the St. Clair River, Mr. Wheeler?

A. The records of the last six years show that vessels use the Detroit and St. Clair Rivers during every month in the year. The broadest definition of season of navigation would include the entire year.

Q. Taking out now the months where the navigation is comparatively small.

A. During January, February and March the number of vessels is very small, averaging less than 50 per month. In April, the number of vessels is from one to 2,000. In December it varies between 700 and a thousand. I should think a better definition of "season of navigation" would be from April to December, inclusive.

Q. What do you mean by ice effects, as they are used in connection with the St. Clair River?

A. I understand ice effects to be the effects which ice has on the discharge and elevation of the rivers and lakes. Ice, when actually present in St. Clair River, tends to retard the flow, and to raise the level of Huron. These are one kind of ice effects. After the ice disappears, the increased elevation of Huron caused by the ice tends to accelerate the flow in the river, and diminishes the elevation in the lake.

Q. Is there any other kind of ice effects?

A. I think that would include them all. These are also ice effects, but of another kind; one or the other kind is always present. In the aggregate the two kinds are equal to each other. There are times when both are operative, and the final result is the difference between the two. Ice effects are sometimes cumulative; that is, the cold months of winter may raise the level of Huron more than can run down in the warm months of summer. Ice effects are very erratic in their intensity. They may be large for several consecutive years, as they probably were from 1880 to 1886, when the level of Huron was raised one foot. Or they may be small, so as to be almost negligible, as they probably have been in the last few years. The retarding effects of the ice must be small during the season of navigation, generally so small as to be negligible, but this may not always be the case. For example, during the period from 1880 to 1886, it is probable that there were large retarding effects during the months of April, May and December. The retarding effects of ice are present, whenever there is any ice.

There is often ice in the river before the first of December, and therefore the retarding effects generally begin before the first of December. But the December ice is often so thin and broken that its retarding effects may be negligible; and I should say that as a rule it is not large enough to be measurable before the middle of December.

Q. How about the effects in April and May?

A. There is much ice in the river in April; generally broken by passing boats. The retarding effects last as long as there is any ice, but it is usually small by the middle of April. Sometimes ice effects last through May. I should say that the retarding effects of ice would generally be unimportant after the first of May.

Mr. Lindley: What river are you talking about now?

A. St. Clair.

Mr. Wilkerson: How about May?

A. There have been, though rarely, large ice jams in May, and retardation during the whole month. There have also been, though rarely, years when there was no ice in May, and therefore no retardation. I should say that more than half the time the ice effects in May are unimportant.

Q. What information can you give us about ice effects in the St. Mary's River?

A. In St. Mary's River the ice raises the water at the foot of the locks during the winter months, sometimes as much as two feet; an average of 20 years shows about six-tenths of a foot. Above the locks no ice effects are observed.

Q. The observations which appear on the charts which you have examined, and from which has been deduced the lowering effect upon the lake level of the diversion of water at Chicago, the observations, as I understand it, most of them were made out of what you call this ice period, were they, Mr. Wheeler?

A. Made in the summer season.

Q. Made in the summer season. By that you mean the open season?

A. Yes.

Q. What they call the season of real navigation, as distinguished from the season when navigation is practically closed, although during the closed season there are a few boats that pass. Is that right?

A. Yes, that is right.

Q. Now I wish you would take up this subject, Mr. Wheeler, and in your own way give us your conclusions with reference to it. The subject is this: The bearing, if any, which the presence of ice during these winter months has upon this lowering effect of the diversion of water in Chicago; I mean not the actual level of the lake, but upon the lowering effect, the tendency of the diversion, whether it would be to lower the level more than what it otherwise would be?

A. I understand that the ice effects do not in any way increase or diminish or change such quantities as the precipitation, evaporation and final outflow, but it has a disturbing effect which might be compared in one sense to storms. It raises the elevation of the lakes at times. It diminishes the outflow of the river at times. It increases the outflow of the river at times, but as it makes no change in the outflow, it makes no change in the effect of a diversion.

Q. That is to say, if I may interrupt you, in order to get

your idea clearly before us, the presence of more ice for instance in the St. Clair in a given winter is a circumstance that is analagous to more rain, for example, is that right?

A. Would you repeat that question.

Q. I say the presence of more ice in the river in a given winter is a circumstance which would be analagous to there being more rain at a given time.

A. Well, in a limited sense that would be true.

Q. I am speaking now in its relation to the lowering effect, so far as it would modify the lowering effect.

A. Well, I should say that it would change the rate of the lowering, but not its final amount.

Q. Well, suppose you compared it with the wind blowing up stream, on the St. Clair river?

A. That would be analagous in a certain respect. It would diminish the current in the river for a time and later the current would be accelerated because of the water that was held up. But the final result would be that just as much water ran down with the wind as would have done without it, and that is true of the ice effects. The total discharge is not affected by it, although the rate at different times is made variable.

Q. What can you say, Mr. Wheeler, with reference to the relation of this ice retardation to the increment of the outflow in the river?

A. I should say that I know of no reason why it should change it. It is a physical possibility that it might so alter the form of the outlet that it would change the value of the increment, but I can see no reason why it should do so.

Q. Now take these two things: The diversion of the quantity of water from Lake Michigan at Chicago, and the fact that some time in the year there is ice in the St. Clair river. What is the relation of the presence of this ice to the ultimate lowering tendency, if any, of the diversion of the water at Chicago?

A. I think it does not change it in any respect.

Q. That is to say, if a diversion of 4,000 cubic feet of water per second at Chicago had certain definite lowering tendency upon the water in Lake Michigan, upon the level of the water in Michigan and Huron that ultimate lowering effect would remain, even though there were ice in the St. Clair river. Is that the result of your answer?

A. It would, I think. The rate at which that lowering would proceed would, I think, vary somewhat on account of

ice. It would be increased in the winter season and diminished in the summer season, but the ultimate effect, which I believe was your question—

Q. I am speaking about the ultimate result about which you testified yesterday. You said, as I understood you, that the diversion of this water at Chicago had a lowering tendency that while the lowering tendency was never absolutely realized because of the law which you expressed yesterday, yet within a few years substantially all of it would be accomplished?

A. Yes.

Q. Now I am asking whether the presence of this ice in the St. Clair River in any way modifies or affects what you have already stated as to the lowering tendency of the diversion of this water?

A. I don't think that it does. The ultimate effect would be just the same. It is similar to that of a great storm on the lake which might change the rate of the discharge temporarily, but it would not change the ultimate lowering effect of the diversion.

Q. And in your judgment would it have any appreciable effect upon the time which would elapse before this lowering effect would be substantially accomplished?

A. I don't think that the effect would be appreciable. I can conceive that there might be some possible slight effect.

Q. Would it substantially modify the time?

A. It would not.

Q. Have you any information Mr. Wheeler, as to whether the St. Clair river is changing its regimen by scouring out its bottom or banks, so as to make a greater outflow from Lake Huron. If so, to what extent is the scouring taking place, and what is its effect on the level of lakes Huron and Michigan?

A. The Board of Engineers on Deep Waterways in 1900 say: "The mean level of Lake Huron is apparently one foot lower than it was fifteen years ago, which change has resulted from enlargement and deepening of the channels for waterway improvement and from the natural erosion of the bed of the river at the outlet of the lake."

This opinion of the Board caused some alarm. The United States lake survey directed a new survey and an examination of all old ones. Assistant Engineer Haskell reported that: "Surveys of the outlet made between 1867 and 1900 do not indicate any enlargement or lowering of the outlet." It

was further pointed out that while an enlargement of the outlet might explain the fall in Huron from 1886 to 1892, it would not explain the rise from 1880 to 1886. The most convincing proof that there has been no enlargement of the outlet comes from the relations between the levels of Lake Huron and Erie since 1886. Thus if Lake Huron had been permanently lowered one foot about the year 1886, the slope between Lake Huron and Erie would be one foot less after 1886. An examination of the records shows that during the twenty years between 1860 and 1880 (before the supposed subsidence of Lake Huron) the mean difference in level between the two lakes was 8.52 feet. For the twenty years between 1887 and 1897 (after the supposed subsidence) the mean difference was 8.47 feet. This close agreement shows that there has been no measurable subsidence of Lake Huron. The continual degradation of all stream beds is recognized, and it is probable that there is some small wearing in the outlet of Lake Huron, but not enough in the last fifty years to be measurable.

Q. What is the diversion from Lake Erie into the Welland Canal and the Erie Canal?

A. Through the Welland Canal, it is given as eleven hundred seconds feet.

Q. You say it is given as that. Where is it given?

A. This is given by the officer in charge of the canal, and I think that his title is Custodian of the Canal. It was obtained from him by correspondence. I gave it in my report in 1903. That can be found in the Chief of Engineers' report for 1903.

Q. Now about the Erie canal?

A. That is 1200 feet per second.

Q. Any changes since then?

A. I know of no changes since then. Both of these quantities were given in that report of mine, 1903.

Q. Is there any other outflow from Lakes Michigan and Huron, except through the St. Clair River and the Drainage Canal?

A. I don't know of any and I don't think that there is any. I don't think that it is possible that there is any.

Q. Suppose there was such an outlet, and it had a discharge, what bearing would that have upon the conclusions you have stated as to the lowering effect of the diversion of the water at Chicago?

A. It would make no change whatever, for our conclusions

and determinations are made from what is actually flowing above ground and in sight; and it would be of no importance if there was a subterraneau outlet, it would make no change in our results.

Q. Do you know of any inconsistencies in the outflow volumes of the St. Clair, Niagara and St. Lawrence Rivers, which are not accounted for by the ice retardations about which you have testified?

A. In a report dated 1893 I say: Formerly there was an inconsistency between the derived discharges of St. Clair, Niagara and St. Lawrence Rivers; but the investigations of ice effects have corrected the derived discharges, so that their relations are entirely reasonable, and there is no longer cause for the theory that a part of the discharge from Lake Erie passed by underground percolation into Lake Ontario.

I have the same opinion now. It is easy to see how these discrepancies, supposed discrepancies, occurred. The discharge through the St. Clair River is always measured in the summer time, in the open season when, as has been before stated, the outflow was accelerated and increased by ice effects. Therefore, the measurd values were always larger than the mean; and when we come to compare it with the Niagara River the two were found to be nearly of the same size. Considering the drainage basin of Erie this was impossible, was absurd, but since the effects of ice on the measurement in the St. Clair River have been recognized, there is no disagreement now in the relative sizes of the two rivers.

Q. Are you familiar with the hydraulic measurements which have been made in the St. Clair River and in the Niagara and St. Lawrence River, and with the management in charge of that work?

A. Mr. L. C. Sabin was in local charge of the St. Clair work, and Mr. E. E. Haskell and F. C. Shenehon in charge of the Niagara and St. Lawrence work.

Q. Having in mind your experience as an engineer, and having in mind the study which you have given to the results of their work, what have you to say as to the degree of accuracy with which it was done?

A. They were all competent engineers, and their work has been reckoned of the highest order, as is indicated by the fact that all are now in positions of responsibility. I consider their work of the highest order.

Q. And what you have said in that answer applies to the

observations which have been platted on the charts which have been exhibited to you here and about which you testified?

A. It does.

Q. When you were on the stand yesterday, we went briefly into the subject of the probable error of the increment of outflow as determined from these observations. You have made, I understand, a careful and particular examination on that subject, and I would like to have you testify now more in detail about it, if you will, Mr. Wheeler.

A. The increment is determined—I determine it by computation. It is given graphically for better illustration on these sheets. The probable error means that quantity which the truth is as likely to exceed as to fall short. It does not mean that the error cannot be greater, but it means that it is as likely to be less as it is to be greater. That applies to the observations that were used. It does not apply to all determinations that might be made. For example if these same quantities were redetermined several years hence, they might differ from the present determinations by quantities greater than the probable error. The several increments with their probable errors are: St. Clair River 25,200 seconds feet± 227 seconds feet. Niagara, first section, 21,867 seconds feet±157 seconds feet. St. Lawrence 28,338 seconds feet±264 ± 143 seconds feet. St. Lawrence 28,338 seconds feet± 264 seconds feet. That is as badly determined as any, but all are believed to be well determined.

Whereupon a recess was taken to two o'clock, p. m.

April 20, 1909, two o'clock, p. m.

Direct Examination of Eben S. Wheeler, resumed.

Mr. Wilkerson: Q. When we adjourned this morning, there had been a question put to you with reference to the meaning of the term "increment" as it has been used in this connection, and its relation to the diversion of a given quantity of water from the lake at Chicago, for instance. I would like to have you go ahead now with that explanation?

A. "Increment" means the number of cubic feet per second that the discharge of a stream is increased by a rise in its surface of one foot. The increment of St. Clair River is 25,200 seconds feet; therefore the fall caused by any diver-

sion has the same ratio. For example a diversion of one-half of 25,200 seconds feet would cause a fall of a half a foot and proportionately for any other amount of diversion.

Q. The fall of Niagara River I think is 308 feet approximately, isn't it?

A. It is, the total fall.

Q. The total fall of Niagara River?

A. Yes, sir.

Q. What then would be the loss in power to that river of the diversion of 14,000 cubic feet per second at Chicago?

A. 14,000 seconds feet of water falling 308 feet has a theoretical potential of 490,000 horse power. If 14,000 seconds feet are diverted at Chicago, it will diminish the theoretical potential at Niagara 490,000 horse power.

Q. That would be true proportionately would it for the diversion of a smaller quantity of water?

A. It would.

Q. What knowledge have you, Mr. Wheeler, on the subject of data regarding evaporation from the basin of Lakes Michigan and Huron?

A. In a report dated 1902, I found the evaporation from the Michigan and Huron basin to be 208,000 seconds feet. This is from a mean of sixteen years. Evaporation is largely controlled by temperature, the wind, humidity, rainfall, etc. These elements are variable and erratic, making the determination of evaporation difficult and uncertain. I do not think that the evaporation in the basin of Michigan and Huron could be determined for one year with a probable error less than 20,000 seconds feet.

Q. Well, in view of the consideration which you have given to data relating to evaporation, precipitation and so on, what have you to say with reference to any attempted deduction which was based upon these alleged data as to evaporation, precipitation?

A. Well, as I think my own determinations had a probable error of ten per cent., I should not expect any results derived from that determination to have any less error than that.

Q. Is there anything else that you can say with reference to the source of those data, that would be further explanatory of your statement that there is a large probable error?

A. Well, the data concerning all of these elements—

Q. I will refer for instance to the extent of territory

covered and the distance apart of the stations where observations were made, things of that kind?

A. I was going to say that it was taken from the Weather Bureau's records, and their records are made at a large number of stations, but with the area so large, the distance between stations is great, and the determination at a single point only gives the correct result for that point, and the mean result of a large area cannot, necessarily, be as close to the truth. The elements, wind for example, is measured at their stations, and very varying results are obtained. I remember that one year at Chicago, the wind records, or the anemometer was changed from a building here in the city out to the crib, with the result that the wind velocity at Chicago was reported after that about twice as much as before. This illustrates the uncertainty of that kind of observations.

Q. In the very nature of things is it possible that with reference to observations concerning evaporation, precipitation, and matters of that kind, there should be anything like that accuracy of observation which is possible in measuring the outflow through the St. Clair River, for instance?

A. No, the outflow through the St. Clair River is measured with much greater accuracy than the rainfall and evaporation can be measured.

Q. Is the difference so great that it can be said that the only class of data, those relating to the outflow through the St. Clair River, can be used as a basis for obtaining accurate results, while the other class of data cannot be used as the basis for determining anything like accurate results?

A. Why I should say for example that the discharge of the St. Clair River has been determined and can be determined with ten times the accuracy of the evaporation of the Huron and Michigan basin and lakes; I should say that there was at least that ratio between them.

Q. In the course of your examination on yesterday, I think in a general way you went over the subject of the length of time which it would take for the ultimate effect of the diversion of the water at Chicago to be accomplished. I direct your attention to that subject again, and ask you if you are prepared to make a more definite statement with reference to it?

A. It will take about four years for a diversion of 10,000 seconds feet to produce nine-tenths of its ultimate effect on Huron and Michigan. A discharge of 25,200 seconds feet from Huron is equal to one foot of elevation. 10,000 seconds

feet will equal 10,000 divided by 25,200, which is .397 feet. Therefore the lake surface will eventually fall .397 feet. The areas of Lake Huron and Michigan is 45,500 square miles. 10,000 seconds feet would cause a fall in one month of .02 feet. This rate will diminish as the lake runs down. At the end of the first year, the lake will be lowered .184 feet. At the end of the fourth year, it will be lowered .360 feet, which is a little more than nine-tenths of the total lowering. But, as stated yesterday, it will take an infinite time to complete the remainder, that is theoretically.

Q. Having in mind, Mr. Wheeler, that the lakes vary in stage from year to year, and that the surface is affected by the influence of wind; it grows rough in storms, and having in mind the other forces which determine the condition of the surface of the lake, what have you to say as to the effect, injurious or otherwise, upon navigation, of the lowering of the level of the lake by say two or three or four inches?

A. I should say that a loss of draft in a fluctuating and disturbed channel is as injurious to navigation as a similar loss would be in a perfectly calm channel.

Q. Why do you say that; that is to say if there is any reason in your mind other than it seems to be perfectly obvious?

A. Why, a loss of draft in a disturbed or fluctuating channel, for example, would tend to cause the boat to strike the bottom. A loss of draft in a perfectly calm channel would also tend to cause the boat to strike the bottom; and the effect in the two cases appears to me to be entirely similar.

Q. How many boats are there on the great lakes that ply between Lake Superior and the lower lakes, or on the lakes below Superior, that are capable of loading to 19 feet?

A. There are three hundred and twenty-three boats that can load to nineteen feet, and of these there are forty-eight that could not safely load deeper.

Q. How many are there to load twenty feet?

A. There are 275 that could load to 20 feet, and of these 87 could not load deeper.

Q. How many could load to 21 feet draft?

A. There are 188 boats that could load to 21 feet draft, or perhaps deeper; some as deep as 26.

Q. Do you know how many tons of freight are carried on all boats capable of loading to 19 feet, traversing the routes which were referred to just a moment ago, during the season of navigation for 1907?

A. Well, in 1907 there were 47 million tons of freight carried through the Sault locks in boats capable of drawing 19 feet of water. Two million tons of this were carried in boats that could not safely load deeper than 19 feet. There were 45 million tons were carried in boats that could have carried more if the channels had been deeper, which is about 85 per cent. of the freight carried on a 19 foot draft.

Q. Now as to boats that could safely load to 20 feet draft, if the chanels had been deep enough, how much was that?

A. Well, 44 millions of tons were carried in boats that could safely load to 20 feet draft, if the channels were deep enough. Of this, 11 million tons were carried in boats that could not safely load deeper than 20 feet.

Q. How much was carried in boats that could safely load to a draft of more than 21 feet, if the channels were deep enough?

A. Thirty-three million tons were carried in boats that could safely load to a draft of more than 21 feet, if the channels were deep enough.

Q. What determines the amount of the load that can be put on these large freighters; that is to say those boats which have a possible draft of more than 19 feet?

A. Well, those points which we have referred to as the critical points, of which the most important is the Sault locks, at the present time. Boats in the Lake Superior trade that can pass the Sault locks can generally pass all other points en route to Buffalo. The vicinity of Amherstberg is the second critical point in importance; and boats in the Lake Superior trade load with the purpose or the object of going through the Sault locks.

Q. In this connection, we have been speaking here of the depth of the water in this Poe lock; it is probably covered by what I have asked you already, but I will ask you again to explain to us just what relation the elevation of Lake Michigan and Huron has to the depth of that lock, and how the lowering of the level of Lakes Michigan and Huron affects the depth of that lock?

A. The lowering of Lake Huron causes a lowering at the foot of the locks of about 75 per cent. My conclusions were that lowering in Huron caused a lowering of 75 per cent. at the foot of the locks.

Q. In the floor of the lock; also of the Poe lock?

A. That is the Poe lock; yes, it affects all those locks.

Q. Having in mind the number of boats now engaged in

commerce on the lakes, that load to the limit, and have to carry a smaller load if the level of the lake is lowered, and that can carry a larger load if the level of the lake is higher, have you made any computation as to the loss to commerce for each loss of one inch of draft?

A. In 1907 there were 323 boats that were carrying up to the load limit. It is estimated that these boats carried fifteen loads each, making 4,841 loads. It is further estimated that one inch of draft in this class of boats is equal to seventy tons of 2,000 pounds each, which would make a total of 239,150 tons. The cost of transportation of iron ore in 1907 was 67 cents per ton. I mention iron ore; that is the lowest priced freight, lowest priced item that there is. This makes the total cost $227,230 for one inch of draft; or the loss of six inches, a half a foot, in 1907 would have caused a loss to vessel men of $1,336,000.

Mr. Williams: It is understood that the testimony taken before the Commissioner is taken with the same understanding as the testimony taken pursuant to stipulation which is attached to the testimony of witnesses Noble, Haskell, Wilson and Ernst.

Mr. Wilkerson: That stipulation I understand is that all substantial objections to the testimony may be urged when it is offered.

Mr. Williams: That is right.

Mr. Wilkerson: But that any objections to the form of the question should be noted at the hearing.

Mr. Williams: That is right.

Mr. Wilkerson: Q. You have been giving us here some conclusions, Mr. Wheeler, which have been based upon statistics. What had you to do in connection with the Poe lock? When were you familiar with the data upon which these conclusions are based?

A. Why, at the present time I am not in local charge of the Poe lock. For a number of years I was, and I looked after the collecting of the data and also designed and arranged the form of reducing it, and publishing it. I am, and was at that time, very familiar with those details; and at the present time they are conducted in substantially the same way as they were then.

Q. With respect to the size of the vessels which are engaged in commerce on the lakes, are those vessels becoming larger or smaller?

A. They are increasing yearly in size, capacity.

Q. Take the next five years for instance: What do you say about the size and draft of vessels that will be engaged in commerce?

A. I have conferred with some of the vessel men, owners and shippers, and some of the large building firms, and they are expecting an increase in the next five years, a small increase. They expect they will have a length of five to six hundred feet; that is nearly everything that is built. A few now have a length even exceeding six hundred. They expect a draft of 21 to 25 feet.

Q. Do you know anything about the dimensions of the large freight carriers of the lakes, that traverse the waters below Lake Superior?

A. The J. P. Morgan has carried a load of 13,800 tons on a draft of 20.2 feet. Her length over all is a little over 600 feet and her beam is 58 feet. The W. B. Kerr has carried a load of 13,300 tons. Her length is 605 feet; beam 60.2 feet. In these boats one inch of draft is equal to 85 tons of freight. This determination was made by getting the difference between the draft of the boat when she was loaded, and light, the amount that her draft was increased by putting a given load on board her. It was easy to determine how much her draft was increased for a single inch.

Q. Do you know how much water is used in the locks at the Sault Ste Marie?

A. It is roughly estimated that 500 seconds feet are used in all of the locks at Sault Ste. Marie.

Cross-Examination by Mr. Lindley.

Q. I understood you yesterday to say in your direct examination that elevation was or is the resultant of a number of elements or forces. Did you use some such expression as that?

A. Yes, I think I did.

Q. I wish you would now enumerate all of the elements or forces which go to make up that resultant, starting in the order of the most important ones, as you consider them?

A. I could not give you all of them.

Q. Just name them?

A. One of the most important is: (a) precipitation, which includes snow fall and rainfall; (b) evaporation, which tends to diminsh the elevation; (c) outflow. These are the prin-

cipal ones. I think it would be hardly worth while to mention or attempt to mention the infinite variety of other things.

Q. That is exactly what I wanted to get at Mr. Wheeler, was the infinite variety; but of course being infinite you cannot name them all, but name as many as you can.

A. That is rather a hard thing to undertake.

Q. I want to get all we can, that is all. I would be very much obliged if you would enumerate all you can name?

A. I could not undertake anything of that kind. You might ask me to classify all the rain drops I should find. I could not do it.

Q. What I do want you to do Mr. Wheeler if you will, is to name all that you can?

A. Well, I have named all that I can.

Q. That is the three, precipitation, evaporation and outflow?

A. Yes.

Q. Didn't I understand you to say yesterday that it also was affected by humidity?

A. The evaporation is affected by humidity, and indirectly that would affect the supply, I suppose. I said that evaporation was affected by humidity.

Q. And seepage?

A. Well, I don't know that I would classify seepage; that is a part of the inflow. I would not discriminate it from the—

Q. From precipitation generally?

A. Precipitation generally, which would include snow fall and rain fall and hail and everything of that kind that is precipitated into the lake.

Q. Well, then, where will you classify wind? I understood you to give that yesterday?

A. That affects evaporation, and it disturbs the elevation of the lake. I don't know that it makes any permanent effect.

Q. That is exactly what I want to get. You used that expression, it is the resultant of various things. I wanted to get what that resultant was made up of, and if you say there are just the principal ones, precipitation, evaporation and outflow, well and good. Then we will try and see what goes to make up those three things.

A. Well, I said that evaporation was caused largely by four things; rain fall, temperature, wind and humidity.

Q. Yes.

A. And as evaporation affects the elevation of the lake's surface, those four things indirectly do it.

Q. As to precipitation, you include in that simply snow fall and rain fall?

A. Yes.

Q. Nothing else?

A. Nothing else.

Q. And in outflow, you include exactly what?

A. The discharge at the outlet.

Q. The discharge at surface outlets?

A. Yes.

Q. Now are you prepared to say that it has been thoroughly demonstrated that there are no subterranean outlets?

A. I am well convinced that there are none.

Q. Do you think that that is an accepted proposition?

A. I think so. Dr. Gilbert of the Geological Survey in speaking of that said that the land between the lakes was known to hold gas, and he believed that if it would hold gas that it would water, and that there would not be any percolation through it, could not be. But it has not been—you ask if it has been thoroughly demonstrated. I can't say that it has, but I am very well convinced that it is true that there is no percolation of water from one lake to another.

Q. As a subject of investigation, however, it is still an open question, open to investigation?

A. Yes.

Q. Referring to the quotation which you just made a moment ago as to the gas, at what depth generally do we obtain gas?

A. The gas that is being found nearest here, over in Canada, is at the depth of between four and five hundred feet, but in other places it is often more than a thousand feet.

Q. Most generally below the level of the lakes is it not, below the level of the bottom of the lakes?

A. Yes, below the level of Lake Erie; not below the level of Lake Superior, however. Still it is often found in deeper localities than the bottoms of any of the lakes.

Q. While you are speaking of the level of the bottom of these lakes, can you give us the average depth of these lakes?

A. Well, I don't think I can give you the average depth. I can give you the deepest sounding that has ever been made in Lake Superior, very closely; I believe it was 1007 feet, something like that. I happen to remember that because I

assisted in making it. As for the average, I don't remember those things.

Mr. Lindley: I take it some of the exhibits that will be offered will show all the soundings which have been made.

Mr. Wilkerson: We will agree on what that shows.

Mr. Lindley: So I do not care to ask any further questions on that.

Mr. Wilkerson: We will make up a table.

Mr. Lindley: Q. You speak of evaporation. What do you include in the term evaporation?

A. All of the moisture or water that rises in the form of vapor into the atmosphere, after having been on the surface of the earth once; goes back into the atmosphere in the form of vapor, vapor of water.

Q. As you use the term, does it also include what the earth absorbs?

A. No, I don't understand it to include that.

Q. How do you arrive at the amount of evaporation, which you give at something like 208,000 seconds feet?

A. I obtained from the records the precipitation in the basin.

Q. On the surface of the lake, and in the run-off area?

A. In the entire basin, which includes of course the lake. Without saying this for reference, I might say I give an elaborate description of how I did this in a report that will be found in the Report of Chief of Engineers for 1903. It perhaps will be sufficient for your purpose if I say that I sum up the rain fall at all the stations and made such corrections as appeared necessary from their location, and determined the area of the basin carefully and in this way I arrived at the total precipitation into the lake; into the basin and lake together.

Q. Let me ask you right there: You are speaking of the basin of both Huron and Michigan?

A. Yes.

Q. They were considered as one lake?

A. In the discussion we considered that as one lake; that made one quantity. I took from the records the discharge from the outlet, the measured discharge from the outlet at that time, and the remainder I assumed to be evaporation.

Q. Well, then, by that process, is it not true that you considered that which the earth consumed as evaporation, because all that fell upon this basin or upon the run-off area did not reach the surface of the lake, nor was it evaporated

as we use the term, or go off in vapor. Didn't some of it seep into the earth and remain there?

A. No, not as I understand it. The earth is not constantly receiving water and retaining it forever. There is no more goes into it than comes out. And I assume that during the time that I was dealing with it, there was not any more going into the earth than was coming out.

Q. So that in evaporation you accounted for all the rain fall upon the surface of the earth within the basin?

A. Yes.

Q. And considered it as either having run off into the surface of the lake and been evaporated or being evaporated directly from the face of the earth?

A. That is it exactly. I assumed there was only those two ways to account for it. If one has two of those three quantities, he can determine the third one.

Q. Did you determine the evaporation from the basin of any of the other of the great lakes?

A. Yes, from all of them.

Q. From all of them?

A. Yes.

Q. Did your computation cover more than one season?

A. Yes, it was the mean of sixteen years.

Q. The mean of sixteen years?

A. Yes.

Q. Beginning with what year?

A. I don't remember. It must have been about 1884, something like that.

Q. To 1900, sixteen years coming down from 1884?

A. Yes. It might have been a little earlier. The time was governed by the character of the records which the Weather Bureau had. They improved their records very much a certain year, and I went back and included that and didn't go any further back. It made this sixteen years that I say.

Q. Your computation was based upon the weather reports from the various stations?

A. Yes.

Q. And those reports were kept by the government officials in the ordinary course of their official duties, is that right?

A. Yes.

Q. And in your judgment are the most reliable extant?

A. Yes.

Q. And the computation can be made with accuracy from

the data given, but the data is not as full as might be, is that it?

A. That is the point exactly.

Q. In your judgment were the number of stations where records were kept by the government sufficiently great and sufficiently well distributed over the area as to give approximately a correct result of the precipitation?

A. Why I estimated within ten per cent.

Q. Within ten per cent?

A. That is not a very close approximation.

Q. Do you recall what the variation was in the way of precipitation during the sixteen years?

A. That is one year with another?

Q. Yes.

A. I do not, further than it was very great. There were certain dry years and certain wet years, and the range of observation of precipitation was very great.

Q. Speaking of dry seasons and wet seasons, do you mean by that taking a calendar year as a whole, or was it that one calendar year for instance with another would be about the same, but different portions thereof would differ greatly?

A. One calendar year with another would vary very much, vary 50 per cent. perhaps in extreme cases, and portions of years would vary still greater. This is as I remember it. It has been a long time since I have been looking at it, and I am not expected to give very accurate answers to these questions.

Q. No, sir. That will all appear, however, from this report which you have referred us to?

A. Yes, I have given it fully there.

Q. If as a matter of fact there should be found to be subterranean outlets or inflows, would there be any possible way of telling how much if any variation there was in the discharge therefrom or the flow thereto?

A. That is a hypothetical question, I think, where you would have to define what the condition of this subterranean outlet was, whether it was in a measureable condition or not. I don't know of any outlet likely to be found, except the ordinary percolation through strata that permits percolation, and that is very difficult to measure.

Q. There is, is there not, around the whole bank of the great lakes more or less percolation from the soil into the basin of the lake?

A. Yes.

Q. So that whatever you may call it, it is in a manner a subterranean inflow?

A. Yes, it is under the surface.

Q. Now that inflow takes place at all distances below the surface, down as far as the bottom of the lakes?

A. Possibly.

Q. Through different strata?

A. Yes, possibly.

Q. And it is not affected, is it, by the rainfall on the surface of the earth, after you have gone down any distance at all, any substantial distance?

A. Why, it is caused entirely by the rain fall. If there was not any rainfall on the surface of the earth, there would be no percolation through it.

Q. Rainfall in the basin?

A. In the basin, yes.

Q. Might it not be that, say going down a distance of fifty feet, that the percolation below a fifty-foot depth would remain constant, no matter what the rainfall in the basin would be?

A. No, not as I understand it; that would be impossible. Its supply must come from some source, and it would soon exhaust it, if there was no longer any supply.

Q. Isn't it possible when you get down a considerable distance that the supply would come from further away than within the basin?

A. Outside of the basin?

Q. Yes.

A. Yes, it is possible that there might some come into the basin from the outside. It is also probable that an equal amount would go from the basin out.

Q. In other words the percolation there would act just like the inflow into the deep wells, would it not? If you get wells sufficiently deep down into the rock strata and different kinds of strata, slate strata, the inflow into that well is not affected by the lack of rainfall on the surface?

A. I don't understand it that way.

Q. In the immediate vicinity, I mean, of the well?

A. Well, it is not affected instantly by a shower in its neighborhood, but its original source is the rainfall, and if there was no rainfall there would be no percolation.

Q. Exactly, somewhere, but not in the immediate vicinity?

A. It comes from somewhere.

Q. It is true, in what they call the arid region east of

the Rocky Mountains, that they are now getting wells at a sufficient depth that have water in abundance, where they never have any water scarcely upon the immediate surface, or for some hundred miles around there?

A. Yes, that is possible.

Q. And if the percolation into the great lakes were of the same character, it would act accordingly?

A. Yes.

Q. Is it possible, Mr. Wheeler, assuming that this inflow into the great lakes around its banks, in the form of what we speak of as percolation, if instead of being what we commonly think of as percolation, that it comes in there in heavy veins as we might say, so much so that it would almost be a stream, is that so?

A. I don't know of any such thing as that; I don't think it is so.

Q. You have seen them dig wells into the slate, and all at once they strike almost a river of water; at least the water comes up in the wells so abundantly so that they do not even have an opportunity to wall the well?

A. Yes.

Q. Is it not probable, not only probable but likely that there are such subterranean streams or veins of water flowing into the basins around the great lakes?

A. I think it is not probable at all; I think it is very unlikely that there is anything of that kind. I am not prepared to say that there is not.

Q. Where you get this water by the boring of wells and the digging of wells, where does the water come from and where does it go to?

A. Why it comes from the surface of the earth in that vicinity somewhere, more or less remote from the well, and where it goes to is usually—it is taken out of the well; there is no stream there, no flowing stream. The well can easily be exhausted; it don't usually amount to much. You cannot pump much water from the well.

Q. You have seen them where they afford considerable water though?

A. Some wells furnish a good deal of water, but nothing like a stream. You can't get enough for a water power out of it.

Q. Have you ever been through the copper mines of northern Michigan, Mr. Wheeler?

A. I have been in some of them, not very thoroughly though.

Q. Are you aware of the depth of those mines?

A. I know the depth of some of them; some are deeper than others.

Q. Some are 2,000 feet, are they not?

A. There are some 5,000 feet; some more than a mile deep.

Q. Are you cognizant of the inflow of water into those mines, at depths far below the level of these lakes?

A. Why, the wet area, the wet depth is less than 400 feet. Usually the miner will say they don't get any water below that. If they get below that they get into the dry dock, I have understood.

Q. Are you personally cognizant of the inflow—

A. No, I never—

Q —into those mines, of water?

A. I never had charge of the sinking of any pits as deep as that. But I know that the first 400 feet is what they call the water bearing depth, and if they get below that they do not expect to have any more trouble with water.

Q. Assuming that there was a stream, subterranean stream flowing into the basin of the lakes, at a considerable distance below the surface, or near the bottom, and that it was a stream of considerable size, would the depth of water above it have any effect upon its flow into the basin?

A. Yes.

Q. What would be that effect?

A. Why, its source would be somewhere higher than the surface of the lake, and if the surface of the lake was increased, then the slope of this stream, this imaginary stream, this supposed stream would be less. If the surface of the lake was lowered, the slope of the stream would be greater and probably its flow would be greater, if its supply remained undiminished.

Q. That is the flow into the basin would be in the reverse proportion to the depth of the water above it?

A. In case the supply remained constant.

Q. That is the pressure of that water above would have an effect on that flow in, would it not?

A. Yes.

Q. And the greater the pressure the less the flow?

A. Yes.

Q. And that would be the effect on any number of these streams of water flowing into the basin of the lake?

A. Yes. It is equally true with a stream flowing on the surface.

Q. Yes, sir.

A. The surface streams just the same.

Q. Exactly; the higher you raise the water in the main body, into which the smaller stream discharges, it has a tendency to block the water in the smaller stream, doesn't it?

A. Yes. It all goes into the lake, just the same.

Q. Eventually?

A. It gets in just the same. That is another question though.

Q. From the surface.

A. Yes, from the surface.

Q. Because there is only so much of it on the surface, and eventually it all gets in?

A. Yes, sir.

Q. Coming back to the question of evaporation just a moment, Mr. Wheeler: The impression which I get from your answer would be that all the water which falls upon the run-off area gets into the lakes, except that which is simply evaporated from the surface?

A. Yes.

Q. Now, as a matter of fact, the relative proportion of the amount of the precipitation upon the run-off area, which actually does get into the lake itself varies greatly, does it not, from season to season?

A. The proportion of the—

Q. Of the precipitation upon the land area in the basin?

A. Do you mean that the evaporation varies, so that the part that gets into the lake varies?

Q. In proportion to the total amount that falls?

A. Why, yes—

Q. Did you use the term, the run-off varies?

A. The run-off, that is a suitable term; why, yes, the evaporation varies from year to year, and if there is a year when there is great evaporation, then there is a smaller proportion of precipitation that gets into the lake, for that year.

Q. Now in other words the proportion in the run-off varies greatly from season to season?

A. Yes.

Q. Well, the level of the lake would be greatly affected would it not, by the proportion of the run-off to the whole precipitation?

A. Yes, sir.

Q. So that as a matter of fact, the same amount of precipitation in one year might affect the level of the lakes a great deal more than the same amount of precipitation in another year, because of the condition of the earth's surface upon which it fell?

A. Yes, on account of evaporation; more evaporation one year than another.

Q. Now the evaporation from the surface of the lake itself depends largely upon what one thing?

A. Why, it depends upon those four elements that I spoke of, but the most important one is the temperature and the second in importance is the rainfall; the third is the wind and the fourth is humidity; and the other elements that affect evaporation are numberless. But the Weather Bureau say that these four make at least nine-tenths of the changes; are caused by these four elements.

Q. What the layman usually speaks of as evaporation, he thinks of that which goes away in the form of vapor; that depends largely upon temperature, does it not?

A. Temperature is the largest of these. It depends very largely on rainfall; the evaporation is very much accelerated by the rainfall. That has been explained to me in various ways, why a rainfall should make increased evaportion, but it does increase it very much.

Q. Around this city, Mr. Wheeler, and in cities surrounding the lakes, south of here and elsewhere, there are a number of artesian wells?

A. Yes.

Q. A number of hundred feet deep. I think some of them in Chicago are in the neighborhood of 1700 feet in depth, comparatively with an inexhaustible supply of water?

A. Are they flowing?

Q. Flowing wells. What would you say was the source from which the water came. Let us assume that they only come within 50 or 60 feet of the surface, then what would you say?

A. Your question is, where does the water come from?

Q. Yes.

A. Why, it is some area that is 50 or 60 feet higher than Chicago at least; may be much more than that. I do not understand geology very well, but the geologists say that artesian wells are caused by an inclined permeable strata of rock, one edge of which is exposed on the surface, and it goes down at an angle, so that it gets lower and lower; and water

percolates in and fills up this strata and it remains there, would remain there infinitely, would be as permanent as the rock itself, until from some cause or other—we will say an artesian well—it is tapped at its lower extremity or somewhere near its lower extremity. Now, water will rise in the artesian well to the same height as the source that filled this permeable strata, this inclined permeable strata.

Q. It will rise voluntarialy without pumping?

A. Yes, without pumping. And when the surface of the earth is lower, where the well is bored, than the source of supply is, then it spouts up and rises above the surface of the earth. And these are not streams of any considerable size; they are soon exhausted. The supply in this permeable strata is generally soon exhausted; but in some of them it is carried on so rapidly from its upper source that the artesian well has a continuous flow; always discharging from it. So I should say that for any of these wells there is some such a phenomena as that. There is an inclined permeable strata that carries the water down to the bottom of it, and its source is higher than the surface around Chicago, and they have been tapped or pierced by an auger and the water comes up and will rise to the same height as the source, whatever that may be.

Q. If the strata, the slant at the angle which causes this artesian effect, as you say, ran into the lake, there would be that discharge into the lake, would there not?

A. Yes, it would be there in the nature of a spring, only it would be under water.

Q. And if a strata started from the bank of the lake, so that the waters seeped above it in a slanting direction, it might be the cause of an artesian well hundreds of miles away?

A. Yes. And I think that I see the point you are making, which is correct. I should say that there may be such things as that coming from outside of what we recognize as the drainage basin. Some water might come into the basin from what we call the limits of it; we haven't got the limits quite right.

Q. Yes.

A. There is not likely to be much of it, and there is as much of it would be likely to go out as come in, and no very great error in taking the limits as we have taken them, as they show on the surface.

Q. But it is not only likely, but more than probable that

there is more or less of that going on, both coming into the lake and going out from the lake?

A. Yes, I should say so.

Q. And that it necessarily follows that these things are some of the elements which enter into that resultant, namely, the elevation of the great lakes?

A. That may enter into it. The flow of water through permeable strata is very slow, very insignificant. I obtained from Mr. Davis of the Geological Survey, only a year or so ago, data in regard to that; and a flow of 12 feet a day is a rapid one, and a flow of only about three feet a day is an ordinary flow.

Q. Would you say, Mr. Wheeler, that if there were a series of wells dug or drilled around Lake Michigan, at say a very short distance, a quarter of a mile therefrom; and that all these wells were what we term ordinary strong wells with a good supply of water, would you say that that water came from Lake Michigan, or was on its way into the basin of Lake Michigan?

A. I should have to examine the case. It would be as likely to be one way as the other.

Q. But there is no doubt is there that all around the great lakes, and within the whole basin of the great lakes, there are innumerable wells all of which are supplied by subterranean supplies, either going into or coming from the great lakes?

A. Yes.

Q. So that it follows that there is an outlet or outflow, with an inflow through the entire water shed area of the great lakes, underneath the surface of the earth?

A. Yes.

Q. And the amount of that out-flow—

A. Is insignificant.

Q. —is unmeasured?

A. Oh, excuse me; I thought you were looking for the word.

Q. Is unmeasured, is that right?

A. No, it is insignificant.

Q. No, isn't it unmeasured?

A. Yes, insignificant things can be unmeasured.

Q. And being unmeasured, the amount of it is unknown?

A. Yes.

Q. Your table that you referred to will give the discharge through the St. Mary's River for the sixteen years of which you spoke?

A. Yes, through all the connecting rivers.

Q. Are there available equally reliable statistics showing the discharge through the St. Clair River since 1900?

A. Yes.

Q. Do you know, Mr. Wheeler, whether the discharge through the St. Clair River in, say the last five years, has been greater on an average or less than for five years preceding 1900?

A. I don't know.

Q. Would these tables show?

A. Yes; it is exceedingly easy to determine that.

Q. Assuming that the discharge has been equally as great in the last five years as in the five years preceding the opening of the main channel of the sanitary district, would you say that additional precipitating upon the basin accounted for that fact?

A. I should most likely say that.

Q. If the additional precipitation would not account for it then what would you say?

A. Well, then, I would say that it did not occur.

Q. Well, then, you say that the data are wrong if they gave that result?

A. Something wrong somewhere.

Q. Something wrong somewhere?

A. Yes.

Q. And could not be accounted for, is that it?

A. Yes.

Q. I understood you to say on your direct examination that notwithstanding improvement and enlargements in the Detroit river and the St. Clair river for fifty years, that there had been no appreciable change in the discharge through there, is that right?

A. Yes.

Q. Have you in mind substantially the change which has been effected within that period of time in the cross-section of those streams?

A. No, not completely in mind.

Q. Could you give us your best offhand guess?

A. Well, it is certain that docks, many docks and piers have been built out from the shore, opposite Detroit and Windsor and all the cities along the shore. That has a tendency to contract the width of the stream, at least; and I can't give you any estimate of the amount.

Q. Where is the governing section of the discharge between Lake Huron and Lake Erie?

A. I always want that term "governing section" defined before I begin to talk about it, because I make a good many mistakes when I treat it differently from the way my questioner means. What do you mean by the term "governing section"?

Q. I will be the Yankee and ask, what do you mean by the governing section?

A. I can't tell you very well. I have had a good many long discussions with Mr. Haskell on that very question. I know I did not think as he did, but I will say that there is a section at Port Huron where it has the greatest velocity; that is it is the smallest section in the river and has the greatest velocity.

Q. Well, the layman's idea of the governing section would be the smallest section I would say?

A. I would say then at Port Huron.

Q. A section through the stuff had to go, and for which more room to fill up the rest of the channel—

A. I would say that was at Port Huron.

Q. At Port Huron?

A. Yes, in the rapids at Port Huron.

Q. Have you now in mind, Mr. Wheeler, what change, if any, there has been in the area of the cross-section at that point, since the improvement of the great lakes began, by the federal government?

A. Why, none at all. I think I stated that, that Mr. Haskell looked that up and made a report in—I gave the date of it; I have forgotten it now—on which he testified that there had not been any change in that cross-section; and I have not done the work myself, but I presume that is the case.

Q. I understood you to say, however, that the fall from Lake Huron to Lake Erie had remained substantially the same?

A. Yes, it was substantially the same; it is within a very few hundredths of a foot the same within the last ten years; the difference in the level between the two lakes, the mean difference in the last ten years, is within a very few hundredths of a foot the same as it was before 1880, the ten years before 1880.

Q. I understood you to say a few moments ago, changing

the subject for a minute, that there had been a gradual increase in the capacity of the vessels of the great lakes?

A. Yes, there is quite a uniform increase in them.

Q. In your study of that question, is there any particular period of time in which you would say that there had been a greater increase proportionately than at any other period of time?

A. Why, yes, I should say that the years that followed the opening of the Poe lock, and certain other improvements in the river, gave suddenly an increased draft; a possible draft of three or four feet, three feet about, and the increase in the size of the vessels was very rapid at that time. They built them rapidly, so as to utilize this increased draft. Otherwise I do not know that I could mention any particular era when the increase began.

Q. When was the Poe lock opened?

A. 1896.

Q. So that just at that period there was a spurt in the efficiency of the freight carrying vessels?

A. Yes, if I remember right.

Q. It would be 1896, they say?

A. 1896, I should say.

Q. But aside from that period, accounted for as you say, there has been a gradual development, and increase in the capacity of vessels?

A. That is as I understand it. I am not very conversant with it, but I think that is the case.

Q. What was the capacity of the Poe lock, so far as permitting the passage of vessels, when it was first opened; what draft vessels?

A. Twenty-one feet.

Q. When it was first opened?

A. Yes.

Q. Is it the same now?

A. No, it has diminished; the capacity now is considerably less.

Q. Why is that?

A. The improvements in the St. Mary's River have diminished the slope. The water used to be about two to three feet higher at the foot of the locks than it is now, so the lock has lost that capacity, a couple of feet perhaps.

Q. That was occasioned by a change in the slope in the St. Mary's River?

A. Yes.

Q. By increasing the cross-section of it, is that right?

A. Yes.

Q. What was that done for?

A. For the deepening of the channel, and the improvement of the channel; making the new one at West Neebish.

Mr. Wilkerson: Was that a government improvement?

A. Oh, yes, that was a government improvement.

Mr. Lindley: The improvement was supposed to more than offset the detriment occasioned by the lowering of the water at the miter-sills?

A. Yes.

Q. What was the nature of this improvement?

A. Dredging out channels to a greater depth than they had had before; dredging out channels, the West Neebish is one of the largest ones.

Q. The west what?

A. The West Neebish, we call it; that is the new channel that Mr. Sabin opened two years ago.

Q. Was the capacity of those channels before the improvements made therein less than the capacity over the miter-sill?

A. You mean the draft for boats?

Q. Yes.

A. Oh, it was about the same. The improvements were kept along somewhat together. Sometimes the dredging was not completed, or before it was completed there might be a shallow place in the river which was lower than the miter-sill of the lock; but at the present time there is not any such place; the St. Mary's River itself is everywhere deeper than the lock.

Q. You were stationed at the Sault, you say, for a number of years?

A. Yes.

Q. I wanted to ask you a little more particularly on that, more for my own information than anything else, what you know about the current between Lake Huron and Lake Michigan at Mackinac?

A. Through the river?

Q. Through the Straits of Mackinaw?

A. Oh, through the Straits of Mackinaw?

Q. Yes.

A. Why, I don't know anything from direct observation. I have seen some discussions in regard to it, and I have heard from captains, vessel captains; and have no doubt but that the current is sometimes one way and sometimes another;

but a majority of the time it runs from Lake Michigan into Lake Huron, and it is affected by the wind; certain winds will cause the current to run the other way for a short time, but most of the time it runs from Michigan to Lake Huron; that the drainage basin of Lake Michigan is such that we may compute a considerable discharge through there, and consequently there is—must be some current flowing through, because the waters of Lake Michigan do get into Lake Huron, and they must move through the Straits to get there.

Q. Is there an official record kept by the Federal Government of the movement of the water at that point, showing the current?

A. No, there is not, that I know of.

Q. What is it?

A. There is not. I think some sort of record of that kind was kept by the railroads, when they were establishing ferries a number of years ago, but the government never did that I know of.

Q. Mr. Wheeler, you testified yesterday, if I recollect right, that the computation which you made from the data obtained from the survey of the Great Lakes, something of that kind, from which these tables that have been referred to were produced, was in your judgment within 1 per cent. of accuracy. Is that right?

A. Why, not fully right. I did not say that I thought that the result itself was within 1 per cent.

Q. No, the computation within 1 per cent.?

A. The computation——

Q. That you made?

A. ——that I made, indicated that the result which those observations showed was within 1 per cent. of being right.

Q. Yes, sir.

A. Some of them were that way; some were 20, but there were some that was 1 per cent., I know.

Q. You don't know what degree of accuracy the data themselves represent?

A. In the sense that I made them myself I do not; but in the sense that I know that they were made by competent men, and they have been handled by competent men, I do know that they are trustworthy and reliable.

Mr. Williams: Mr. Wheeler, you just testified a moment ago that the result of the observations made tended to the belief that the waters of Lake Michigan run into Lake Huron?

A. Yes.

Q. And I believe you have testified that generally speaking Lakes Huron and Michigan form one body of water?

A. Yes.

Q. Are you familiar with the fact that in the government reports of elevations of these two lakes, they are given as varying to the extent of five one-hundredths of a foot?

A. No, I am not familiar with that.

Q. Are you familiar with the fact that in the report in Bulletin No. 16 of the Survey of the Northern and Northwestern Lakes, page 97, issued in April, 1906, it appears that the elevation of Lake Michigan is—the mean elevation of Lake Michigan is 581.34 feet, and that the mean elevation of Lake Huron is 581.39 feet, showing the elevation of Lake Huron to be higher than that of Lake Michigan?

A. No, I was not familiar with that.

Q. And you have no explanation to offer?

A. No.

Q. As to why those figures are so given out?

A. No, I didn't make them, and I don't know whether they were so given.

Q. On page 249 of the same document, the discharge through the St. Clair River is given as 206,200 cubic feet per second and the variation or the increase of discharge per foot rise of the lake is given as 19,238 cubic feet per second. Do you know, or have you any information as to the data from which that figure of 19,238 cubic feet per second was obtained?

A. No, I am not familiar with that.

Q. Do you know who made the computations that are contained in this report?

A. No, I do not. May I see what report it is (examining same)? I am not familiar with that at all. That is the Bulletin issued for the benefit of navigators, and I have not had anything to do with it.

Q. What is the relation, if any, between your office and the duties that you perform, and the duties of the Lake Survey?

A. The Lake Survey is engaged in surveying and mapping the harbors and the channels; and the office in which I am employed is engaged in the improvement, the deepening of the channels and dredging them; improvement of harbors.

Q. Are there any surveys made in your office, in your department?

A. Not extensive and general ones. In doing our work it is always necessary to make small surveys in the vicinity

of our work; such as we make for estimates and so on; but none that are incorporated in the published map.

Q. Do you know the method or manner of making the observations of the discharge through the St. Clair River, to form the basis of the plates that have been introduced in evidence?

Q. Yes, I know the general method.

Q, At what point in the St. Clair River was the discharge measured?

A. There have been a number of cross-sections where the discharge has been measured. The principal one is below the rapids and opposite the City of Port Huron, from one to two miles below the rapids.

Q. Now will you state in a general way the method of making these observations. I believe you stated yesterday that first you have a gauge reading indicating the elevation of the lake?

A. Yes.

Q. Now how frequently is that gauge read, or is it read constantly?

A. Why, at Port Huron they have a self-registering gauge, read continuously there, but usually when they are making these observations, it would be read every quarter of an hour. An observer is stationed at a gauge to read it and record it.

Q. What instruments would be used in the measuring of the discharge?

A. The principal instrument is a meter, which determines the velocity. The discharge is obtained by getting the area of the cross-section, and the velocity in that area, and those two factors multiplied together give the amount of the discharge.

Q. Are you familiar with the meters that were in use at the time of the observations that are platted upon these plates?

A. Yes, somewhat familiar with them.

Q. What meters were used there?

A. At that point the Ritchie-Haskell meter, as it is called.

Q. That is the meter invented by Professor Haskell?

A. Yes.

Q. How many of those meters would be used at one point, I mean in the making of one observation there?

A. Twelve or thirteen I think were often used. I don't know how many.

Q. Do you know whether the measurements would be taken of all these meters at the same time?

A. Yes, of a large number of them at least at the same time.

Q. And how far apart would they be located?

A. Well, often they were on one vertical line. Perhaps there would be six on a vertical line, so as to get the velocity simultaneously at six different depths, and the sections in which they were read were 100 feet perhaps, so that transversely across the river they would be perhaps 100 feet apart.

Q. How wide is the river at the point you have mentioned, where most of these observations were probably made?

A. Oh, 1,600 to 2,000 feet, somewhere I should imagine.

Q. And in a vertical line from one shore to the other these meters would be used at varying depths?

A. On each vertical line. When they were observing at a certain point in the cross-section, they did at times have these meters suspended vertically, one of them at the bottom, or as near the bottom as it was safe to use it, and the others at uniform distances perhaps above it, and then in the neighboring section, say, 100 feet further, this operation would be repeated in this place, until the whole section of the river had been so occupied.

Q. What is the greatest depth of the river at that point?

A. I think something like between 40 and 60 feet; I don't know what the depth is.

Q. And that is approximately the center of the stream?

A. Yes.

Q. These observations were taken at stated points, each one at a different distance from the shore, to reach the other shore?

A. Yes.

Q. And how near together, if you know?

A. I don't remember that. I did not take these observations myself. You will have before you a man who knows all about it, who did do it, and whose information would be much more accurate than mine.

Q. Have you an opinion as to the degree of accuracy obtained from the observations made of the discharge, by the use of these meters?

A. Yes.

Q. What degree of accuracy would you say was attained?

A. I should say that they could determine the total discharge at a certain date, a certain time, within 3 per cent. I don't remember what they have assigned—the probable error that is given in their work; that can be easily found.

Q. You have a higher opinion of the Haskell meter than Professor Haskell himself, then?

A. Perhaps I am giving it better than it should be. It is not at all surprising that I do have a higher opinion of Mr. Haskell than he has himself. He is a very modest man.

Q. Have you an opinion as to the degree of accuracy of the discharge measurements in the St. Clair River?

A. Yes, but I would not be able—it would not be at all valuable to give an estimate of the percentage of error, by me, when these matters are accessible and can be known correctly.

Q. Do you think it is possible to know correctly and absolutely the degree of accuracy of this discharge measurement?

A. Well, I will have to explain that to you. I think it is possible to know the probable error; that is, to know a quantity which the truth is as likely to exceed as it is to fall short of; that is all that computers claim for it. An absolute truth is not reached anywhere by any one.

Q. According to your computations, using these plates that are introduced in evidence as a basis, the effect of the diversion of 10,000 cubic feet per second at Chicago upon the level of Lakes Michigan and Huron would be about four and seventy-six one-hundredths of an inch?

A. I think that is what I made it.

Q. At what elevation do you compute that?

A. I think that is true for all the elevations within the range that we have been able to observe it; I do not observe any change.

Q. Is there any difference in the effect of that diversion when the lake is, say, a foot higher than the average elevation?

A. No observable difference.

Q. And the same would be true if it were a foot below the mean elevation?

A. Yes, I think so. These results are only expected to be used within the range in elevation that we have observations. We cannot extrapolate and get it correctly outside of that range.

Q. What is the range of elevation of Lake Michigan, that is within the experience of your office or yourself?

A. I think the records show something like five feet but that should be—the ordinary range is less than three feet.

Q. What would you say as to the natural oscillations in

Lake Michigan and the extent of a change of level, oscillations in the level of Lake Michigan?

A. I don't know that I get the question quite right.

Q. Is it true that the level of the lake frequently changes within a very short time.

A. Oh, yes, there are changes, wind changes, barometric changes; that is in parts of the lake. I do not think that the mean level of the entire lake changes very much in a short time. It takes considerable time for that to be effected; but it is only in parts of the lake.

Q. Do you know the extent of that variation?

A. You mean in parts of the lake?

Q. Yes.

A. Oh, there are known cases of two or three feet.

Q. And continuing for what length of time?

A. Oh, several hours. In Lake Erie, I think wind storms have produced still greater effects than that. They have made one end of the lake five feet lower than the normal and the other end five feet higher, making a slope of 10 feet in the lake.

Q. Are there any causes that occur to you for these oscillations, other than wind?

A. Well, there is the well known seiches.

Q. From the plates that are before you and from which you have testified, is the effect of a diversion at Chicago more or less appreciable in Lake Erie than in Lake Michigan?

A. The difference is so slight that I won't say which is the larger.

Q. I think you testified that the effect of each 1,000 cubic feet diversion would be about five-tenths of an inch in Lake Michigan, and fifty-five one-hundredths in Lake Erie, per each 1,000 cubic feet diversion?

A. There is a slight difference between the two lakes; the effect would be a little greater on Lake Erie.

Q. Taking a diversion of 4,000 cubic feet per second, the effect on Lake Michigan would be approximately two inches, and on Lake Erie two and a half inches?

A. A little more on Lake Erie than Lake Michigan.

Q. Two and two-tenths inches. Now, the lowering of the level of Lake Erie two-tenths of an inch more than the lowering of the level of Lake Michigan would, in itself, have a tendency to lower Lake Michigan further, would it not?

A. Yes, they interact on each other infinitely.

Q. What is the level, or the elevation of Lake Erie as compared with Lake Michigan?

A. Lake Erie is about 8½ feet lower than Lake Michigan.

Q. Have you read the testimony given in this case by Professor Haskell?

A. No, I have not.

Q. Professor Haskell in his testimony states that the effect of a diversion at Chicago would be about 80 per cent. in Lake Erie of what it would be in Lake Michigan. He had before him the same plates that you have. I will ask you whether or not you can account for the difference of opinion that is apparent between your opinion and that of Professor Haskell.

A. No, I have no means of accounting for that.

Q. What would you say as to the accuracy of this general statement, Mr. Wheeler, a statement made by Mr. Wilson, a witness called on behalf of the Government: "In a series of reservoirs such as the Great Lakes are, the effect of diversions generally decrease, as they go down to the source." What would you say as to the accuracy of that statement?

Mr. Wilkerson: Whose statement is that?

Mr. Williams: Mr. Wilson's, Secretary of the International Waterways Commission.

A. If the increment increased as it went towards the outlet, that would be true; but whether it does or not must be determined by the actual conditions as they exist, by measurement. In going from St. Clair to Niagara the increment diminishes; it increases again in the St. Lawrence. Therefore his statement would be incorrect for the Erie section, and true for the St. Lawrence section. But that it is generally true in all systems, I should not agree with that at all. I should want to have it measured, and it might or might not be true.

Q. Would you say that the effect of a diversion at Chicago would be more or less noticeable in the Detroit River than in the St. Clair River?

A. No, I should say that there was no difference.

Q. They would be both the same?

A. They would both probably be the same.

Q. And would it be any more or less noticeable in either the Detroit or St. Clair Rivers than in Lake Michigan itself?

A. Oh, it might or it might not. That is a question that involves the channel conditions to such an infinite extent that no one can give any answer on that at all. If you would

care to look at a curve that was made by the deep waterway people from actual observations, showing the change in level at all points in the St. Clair and the Detroit River for a change in level in Lake Huron and Lake Michigan, you would see that it is different at every point between Port Huron and Gibraltar, and that can only be explained from the character, nature of the channel, its cross-section and the slope and so on.

Q. Would you say then that it was practically impossible to determine the relative effect upon the level of those rivers?

A. Yes. If you like I will get that illustration that I speak of, and I think perhaps you will understand my position better if you will look at it (producing same). It is impossible to determine it accurately, with any very great degree of accuracy, because you can see they do not obey any law between them; that we have discussed and demonstrated to an extent, so that we cannot divide it up into sections and give the functions of each section.

Mr. Wilkerson: You do not mean to say it is impossible to determine whether there is any effect?

A. Let me hear the question once more.

(Question read to the witness as follows: "Would you say then that it was practically impossible to determine the relative effect upon the level of those rivers?")

Mr. Williams: In its relation to the effect upon Lake Michigan; that is what proportion of the effect that is seen in Lake Michigan would be observable on those rivers?

A. On the rivers?

Q. Yes.

A. Well, I would not say it was impossible to determine it approximately.

Q. Accurately.

A. Accurately, it is impossible to determine it accurately; that is for me to do it, because I have not the data.

Q. That is what I mean.

A. I can determine it approximately.

Q. Would it be possible to determine accurately the effect, relative effect upon the level at any one of the critical points mentioned by you?

A. It would be possible, if the proper observations were made at that point.

Q. Do you know whether the proper observations have been made at those points?

A. At many of those points, no observations have been made, and the estimates that I have given, I have given from

the geographical location of the point. They are not expected to have the accuracy that those points which were determined by careful observations have.

Q. What is the low water period in Lakes Michigan and Huron?

A. The recent low water period was in 1895 if that is——

Q. During what seasons of the year would you say that the water is at its lowest stage?

A. I don't remember what month it is; February, I guess.

Q. And generally speaking during the winter months?

A. Yes.

Q. Now have you an opinion, and if so what is it, as to why the water in Lake Huron and Lake Michigan is, generally speaking, at a lower stage during the winter months, when the ice effect would be most noticeable in diminishing the outflow through the St. Clair River?

A. The elevation, as I have had occasion to say, is the algebraic sum of all the causes, and I suppose the reason is the algebraic sum of all the causes producing it.

Q. The tendency of the ice gathering in the St. Clair River is to diminish the outflow through the St. Clair River, isn't it?

A. Yes.

Q. And the diminishing of the outflow would naturally result in raising the level of the lakes, Huron and Michigan?

A. Yes, and then if you ask me the still further question, why don't it make them higher, I say it is because the total height depends on other causes as well, upon the algebraic sum of all of them; that one is not sufficient to do it.

Q. Do you know what the aggregate amount of the storage in Lakes Huron and Michigan was for a period of three years, as shown in the report of the Chief of Engineers for 1903; the storage for the months of December, January, February, March, April and May, caused by the diminished flow, in consequence of the ice in the outlet of Lake Huron?

A. I don't remember what that was.

Q. Suppose that the total stored water for those months aggregated more than the entire year's supply for the Sanitary District's main channel, what would you say as to the effect of that diversion through the main channel upon the level of the entire system of great lakes?

A. How many cubic feet was the diversion that you speak of?

Q. Assume that the diversion was 10,000 cubic feet.

A. I think that I have stated that several times, what it would be. It would be something like five inches.

Q. Would it make any difference that there was more than enough water stored in those lakes during those months——

A. On the effect the diversion had?

Q. Yes.

A. Not a particle. The effect went into the algebraic sum and helped to make it smaller.

Q. What percentage of the effect of the diversion at Chicago of a given amount of water from Lake Michigan would be noticeable in the St. Lawrence River?

A. The amount, do you mean, or the effect on Lake Ontario?

Q. I think you testified with reference to the St. Lawrence River?

A. I don't think I testified anything definite because I have not looked that river up; but the discharge through the St. Lawrence River would be diminished by the same amount as the diversion. Its effect on Lake Ontario would not be as great as it would be on Lake Erie.

Q. You gave the increment of discharge in the St. Lawrence River?

A. Yes.

Q. And how much is that?

A. Twenty-eight thousand and something; I don't remember.

Q. And if you diverted 10,000 cubic feet at Chicago, in your judgment there would be ten twenty-eighths of a foot lowering in Lake Ontario?

A. Yes.

Q. And have you any information from which you can give an opinion as to what the extent of the lowering would be in the St. Lawrence River itself?

A. No, I have not; perhaps such information is available but I don't happen to have it.

Whereupon an adjournment was taken to April 21, 1909, at the hour of 10 o'clock a. m.

April 21, 1909, 10 o'clock a. m.

Parties met pursuant to adjournment.

EBEN S. WHEELER resumed the stand and was further cross-examined by Mr. Williams as follows:

Q. Mr. Wheeler, on your direct examination, I believe that you referred to a report made by you in June, 1903, and shown in Appendix FFF of the report of the Chief of Engineers for that year?

A. Yes, I made such a report.

Q. And that was the report that is contained from pages 2855 to 2862, inclusive, of that volume, which I have indicated?

A. Yes.

Q. What have you to say as to the reliability and accuracy of the computations made and shown and the facts set forth in that report, at this time?

A. The computations were very carefully made and were checked; and contain, so far as I know, no errors.

Q. As to the data contained in the report, what do you say as to the reliability of that data, that is used in the making of the computations?

A. I will say, first, that I believed it to be at that time, and I still believe it to be, the best extant. I will say, second that some of the observations had greater accuracy than other portions; that probably some part of the data, there was an error of 20 per cent.; some part of the data would lead to errors of 3 per cent.

Q. Will you indicate as to the different subject-matters, which data have a probable error of 20 per cent. and which 3 per cent.?

A. I should say that data relating to meteorology.

Q. What percentage of error would you say there was in the data from which you make your computations respecting evaporation?

A. I should not be surprised if there should prove to be 20 per cent. error in that; there may be much less.

Q. And what percentage of error would you say there was in the data respecting rainfall?

A. Tnat is a part of your first question, as I understood it. That includes rainfall.

Q. Evaporation includes rainfall?

A. Yes, it is a function of rainfall. At any rate the answer applies to it.

Q. About 20 per cent.; that is it is possibly 20 per cent. What percentage of error would you say there was in your data from which you made your computations respecting the discharges through the St. Clair, Niagara and the St. Lawrence Rivers?

A. Probably less than 10 per cent.

Q. What percentage of error in your data is there as to the areas of the lakes, Lake Erie?

A. I didn't understand that.

Q. What percentage of error would you say there may be in your data respecting lake areas?

A. That is given in the report. I do not remember it.

Q. I think you gave the areas, but not the probable error?

A. I think I did, page 2856.

Q. You say in order to make an approximate estimate of the error in the determined area of the drainage basin, it may reasonably be assumed that the best located part of the boundary is never more than six miles in error, and this not oftener than once in 100 miles. And you said then that it is probable that the areas are correctly determined within less than 2 per cent.?

A. That is of the drainage basin.

Q. That is the drainage basin. Now as to the surfaces of lake areas, does the surface of the lakes——

A. I think you will find the same thing, the method of determining them is given there. You will find it is stated they were divided into rectangles that were bounded by parallels and meridians.

Q. Can you by referring to your report answer definitely the question as to, in your opinion, a probable percentage of error in the determination of lake areas?

A. Well, I say this much about it at that time, and I could not say any more or better at the present time: "Quadrilaterals, of one degree or less in extent, bounded by meridians and parallels were selected, so as to completely cover the basin. This gave a polygon, the sides of which were meridians and parallels. The total area of this polygon was determined accurately from geodetic tables of areas. Those small parts of the polygon which extended outside of the boundaries of the basin were measured with a plainimeter and subtracted; the remainder being the area of the basin. This work was done with care and checked, and it is believed that the areas of the

lakes and basins as above given on Plate 1 are as accurate as extant maps will permit." I could not say any more than that. A long time has elapsed since doing the work, and I knew better then than now.

Q. You say that the computations made as to lake areas were as accurate as those made relating to the drainage basins?

A. Yes, they are more accurate.

Q. And the determinations would be more accurate?

A. Yes.

Q. What would you say as to the percentage of error in the determinations arrived at with reference to the elevations of the several lakes mentioned in your report?

A. Well, I don't know that I would say anything about it. If one knew what his errors were, he could give an accurate result. It is an unknown quantity.

Q. You have an opinion with reference to it, the same as with reference to the other matters concerning which you have testified, where there was a probable percentage of error?

A. Well, I should say that it was less than 10 per cent.

Q. That is the percentage of error. Does that refer to the computations or to the data from which the computations were made?

A. It refers to the data.

Q. The computations you consider absolutely accurate?

A. So far as I know no errors were left in it.

Q. Is 10 per cent. as near as you would want to testify as to the probable error in the data respecting lake elevations?

A. Yes.

Q. Are we to understand then that these figures shown on page 2867, showing the mean monthly elevation of Lake Superior above the locks at St. Mary's Falls canal, might possibly be an error to the extent of 10 per cent.?

A. You asked what my opinion was, and I said my opinion was it would be less than 10 per cent.; so you are at liberty to understand that.

Q. From the data before you, at the time of making that report, would you now therefore be unwilling to say that, taking, for instance, the elevation of Lake Superior for December that figure, 602.14, might be 662.14 or 552.14?

A. I should be quite willing to say that it would be less than 10 per cent., but I am very unwilling to say what it would be or that it would be more——

Q. I said that it might be either more or less to the extent I mentioned?

A. I am unwilling to testify to that. I think it is less; that is my opinion.

Q. Are you willing to express an opinion that there is a percentage of error in that data of less than 10 per cent.?

A. No.

Q. Do you believe, Mr. Wheeler, that the actual elevation of Lake Superior was either 10 per cent. more or 10 per cent. less than the amount shown by the data to which your attention is called?

A. I haven't any fixed belief on that question.

Q. Are you familiar with the methods by which these elevations were determined?

A. Yes, somewhat familiar with the methods.

Q. Now, taking the Table 4 shown on page 2870 of this report, relating to the mean monthly elevation of Lake Erie at Cleveland, would you answer the questions as to the probable error in the data as to those elevations in the same manner that you did with reference to the data respecting the elevations of Lake Superior?

A. Yes. I have no means of determining it.

Q. And the same would be true as to the elevations in Lake Huron?

A. Yes.

Q. And Lake Ontario?

A. Yes.

Q. Now suppose that as a matter of fact the elevation of Lake Huron was actually 10 per cent. greater, higher than that shown by the data here submitted, and that the elevations of Lake Erie were actually 10 per cent. less than those shown by these tables, would you say then—what would you say then as to the accuracy of the computations, the determinations, made by you on the basis of that data?

A. Why, I should say that the computations were entirely accurate.

Q. As to the results obtained?

A. I should say that the results had had the errors of the observations in them.

Q. Do you think that it would be possible, Mr. Wheeler, that there would be a difference of over 100 feet in the elevations of Lake Huron and Lake Erie?

A. Lake Huron and Lake Erie, a difference in the elevations of over a hundred feet?

Q. Yes.

A. No, I don't think there would likely be any such difference as that.

Q. And yet if there was an error of 10 per cent. in the data respecting the elevation of Lake Huron, and an error in the other direction of 10 per cent. in the elevation of Lake Erie, as shown by this data, it would show a greater difference than 100 feet?

A. I said that I thought it would be less, but I am not inclined to tell you what the error of those observations was, for I know nothing about it; it is an uncertain question.

Q. How much less would you say than 10 per cent.

A. I would not like to say. I can only give you an opinion within limits. This accurate knowledge of the error is impossible.

Q. But 10 per cent. is as near an accurate answer to the question as you would care to go?

A. I don't care to make the limits any nearer.

Re-direct Examination by Mr. Wilkerson.

Q. In your cross-examination yesterday, Mr. Wheeler, you were asked some questions and made some replies with reference to alleged or possible seepage into the lake. What have you to say further on that subject with reference to the effect of that upon the diversion of this water at Chicago?

A. I should say that there is a possible seepage into the lake; that a part of the precipitation may be returned, or get into the lake in that way; that it is entirely immaterial whether it gets in under ground or in surface streams. It has no effect whatever on the Chicago diversion, or in other words the Chicago diversion influences the level of the lake just the same, whether there is much or little seepage.

Q. That is to say if the effect of a diversion of a quantity of water from the lake at Chicago was to lower the elevation of the lake by two inches, that effect would be the same whether all the water came into the lake either by rainfall on the surface, by flowing in on the surface of the land, or whether it seeped in. Is that what you mean?

A. That is what I mean.

Mr. Williams: I object to counsel framing an answer for the witness, and testifying himself. I object to the form of the question.

Mr. Wilkerson: Q. Now, Mr. Wheeler, on yesterday you

were also asked some questions with reference to the elevation of Lakes Huron and Michigan during the ice period, as compared with the elevation during the open period. And you made some explanation of the factors which caused the holding back of the water by the ice during the ice period, not to have the effect of actually raising the elevation of the lake. Now what in your opinion is the cause of that condition?

A. I don't know that I clearly understand the question.

Q. You said that the fact was that during the ice period, the elevation was lower than it was during the other period, as a matter of fact, although the ice did hold the water back?

A. I don't remember that I said that; it may on occasions be that; it is not necessarily that way.

Q. It is that way sometimes?

A. It is that way sometimes.

Q. When that is the case, to what is that due?

A. It is due to the other elements that enter into the elevation of the lake surface; the ice disturbance is only one, and the final effect on the lake surface is the difference between all those that raise it, and all those that lower it.

Q. And the fact that the snow does not melt in the winter would be one of them, I assume?

A. That would be one. That is when it is stored on the shore it permits the lake to run down; when it melts and runs off, it has a tendency to raise the lake.

Q. I would like to ask you a few questions in reference to the elevation, with reference to the probable error in these figures found in this report of 1903, so far as they relate to the elevation of the lakes. Now I understood you to say that you were unwilling to express an opinion that the figures as set down were more nearly accurate than say within ten per cent. of the truth?

A. I don't think I said that. I said I was willing to express an opinion that I expected that they were.

Q. They were within—much below the ten per cent.?

Question objected to by counsel for the defendant.

A. That they were below 10 per cent.

Q. Now the figures that are set down here show the elevation of these lakes in the first place above the sea level, is that right?

A. Yes.

Q. Then there is also a statement of the elevation of the lakes in relation to the locks at St. Mary's Falls, and at Sand

Beach; that is with reference to zero on the gauges at those points?

A. I would have to look at it to see. (Referring to same.)

Q. There is a statement at the head of those columns there, one relating to—

A. These figures have reference to sea level. That means that it is 602.60 of a foot above sea level.

Q. Now, if you take as a standard and assume the accuracy of that figure, the elevation of the locks above the sea level, the wall of the lock above the sea level, then the difference between that figure and the figure which is put down as above the sea level would be the elevation of Lake Superior above that lock wall?

A. Yes.

Q. Did you have charge of these gauge measurements at any time?

A. Yes, for some time.

Q. I wish you would tell us just how those are made, just how you go about determining the elevation of Lake Superior below the lock wall?

Mr. Williams: I object to the question on the ground that it is not re-direct examination.

Q. Answer the question?

A. There is a staff gauge installed at the head of the canal, with a scale with a zero, and the elevation of the zero above the level of the sea has been determined by precise levels. The observer takes a scale resembling a yard stick somewhat, and he measures the distance between the surface of the water and the zero of the gauge which he records in a note book. This he does three times a day. That is one form in which the measurements are made; and that was all the form for many years. But during a part of the time there has been a self registering gauge established which records the elevation in a continuous line, so that the elevation can be found at any instant of time. But the former method enters into these tables much more than the latter one does.

Q. When you have three readings a day, you make a mean of them do you, monthly mean?

A. Yes, that is reduced to a monthly mean and those monthly means appear in those tables.

Q. Now, if we were to assume the accuracy of the figure which is put down as representing the level of the wall of the lock, the elevation of the wall of the lock above sea-level, and the figure which it was desired to obtain was one which ex-

pressed the difference between that and the level, we will say of Lakes Huron and Michigan, and of Lake Superior, what would you say as to the accuracy with which the figure representing that difference could be stated in, we will say, hundredths of a foot?

A. I could say that the work is done by competent observers and the record is accurately made and is properly reduced, and as to what the error which might come in from all other sources in the observations is, I don't know,—I don't like to state. You are asking me something I would like to know about, but I don't.

Q. Do you think that figure has been determined with respect to the elevation of the wall of the lock within one-tenth of a foot?

Mr. Williams: I object; wait a minute.

A. I don't remember—

Mr. Williams: I object to the question as leading, and not proper re-direct examination.

Mr. Wilkerson: Answer the question.

A. I don't remember what the derived probable error is—it has been obtained and can be found in the reports. I should imagine it would be less than a foot, certainly less than two feet. That is an opinion only.

Q. The thing that I want to have clear in the record, Mr. Wheeler, on this question of probable error is to have you explain, if there is any further explanation—if there is anything further that may be added to what you have stated already, the difference between the term "probable error" as you used it in referring to these figures, which represent the elevation of the surface of any one of the lakes above sea level and the term "probable error" as you used it with reference to a figure which will express the difference between the elevations, we will say, of Lakes Michigan and Huron and Lake Superior, or Lakes Huron and Michigan and Lake Erie, without regard to the absolute accuracy of the figure with respect to the sea level.

A. The probable error of the observation is the probable error of that part that was observed. For example, if the difference between the zero of the gauge and the water surface is one foot, and the observer measures one foot and records it, and you ask me the probable error of that observation, and I say that it is less than ten per cent., I mean that I think he has measured it within one-tenth of a foot. It is

measuring the quantity of the thing and observed to which the probable error refers.

Q. And that is what you had in mind when you used the term ten per cent.?

A. Yes.

Q. Now having three observations a day, that would run up to ninety observations in a month, what would you say as to whether or not the probable error in that number of observations would fall much or little within the ten per cent. limit which you named?

A. I should expect, as the observers are competent and careful, that it would be less than ten per cent.

Q. Well, then, when you were speaking with reference to the probable error in these tables, showing the mean elevation of the lake, do I understand that you used the term "probable error" in the sense which you have last defined it, taking its relation to the thing which was observed—

A. Yes, sir.

Q. —and not to a probable error of ten per cent. of 602 feet for instance, when the subject under consideration was the difference in the level between Lake Michigan and Lake Superior—

Mr. Williams: Just a moment; I object to the question as improper in form—

Mr. Wilkerson: I wish you would just explain fully, I want to get here a precise statement of what you mean by that term "probable error."

Mr. Williams: I want the record to show that I protest against counsel putting words in the mouth of the witness and telling him what he wants him to testify to. It has been done repeatedly, and it is becoming worse and worse as we go along.

Mr. Wilkerson: I think counsel, both counsel and the witness, are amply able to take care of themselves, and will be, when the record is submitted to the court. Proceed with your explanation, Mr. Wheeler.

A. Is the question to be answered?

Q. Yes, sir.

A. The probable error of an observation is the probable error of the thing observed. It is not the error of a quantity that may be made up of the observation and many other things added to it; it is the thing observed. That is what I mean by probable error. As I said before, if we measure the distance between the surface of the water and zero, and

that distance is one foot, and the probable error is less than ten per cent., I should say that it was less than one-tenth of a foot. Now it would be easy to determine the distance of the zero of the gauge from the center of the earth, and insert that in the table, and then my statement that it is less than ten per cent. does not mean one-tenth of the distance to the center of the earth.

Q. Certainly; but it means ten per cent. of the thing which has been observed?

A. Ten per cent. of the thing observed. In order to make this clearer, I think I ought to add there is a probable error in the distance above sea level. The quantities in the table there seem to be made up of two things. One is the elevation of the zero of the gauge above the sea level, and another is the elevation of the water surface above the zero of the gauge, or below it as the case may be. Both of those quantities have probable errors and when I am speaking of errors of observation, water level observations, I mean the water level observations. I don't mean the precise level work from there to the sea.

Mr. Wilkerson: That is all.

Mr. Williams: That is all.

Mr. Wilkerson: These pages of the report of 1903 that the witness has referred to in the course of his testimony may be treated as identified by the witness as figures in a report, by you, wasn't it, Mr. Wheeler?

The Witness: By me.

Mr. Wilkerson: Figures in a report prepared by him.

Mr. Williams: Well, the report itself, together with the tables attached thereto, he testified from those observations, showing the elevations.

Mr. Wilkerson: This report may be treated as having been identified by the witness.

Mr. Williams: Yes, sir.

Mr. Wilkerson: Of course, when it comes to offering it on either side the question of the materiality and relevancy may be raised.

Mr. Williams: Of course those are reserved anyway.

Mr. Wilkerson: But the report may be treated as identified by the witness, at the request of counsel for the defense.

LOUIS C. SABIN, a witness called on behalf of the complainant, was first duly cautioned and sworn, and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name, please, Mr. Sabin?
A. Louis C. Sabin.
Q. Where do you live?
A. Sault Ste. Marie, Michigan.
Q. What is your occupation?
A. Civil engineer.
Q. In the government service?
A. Yes, sir.
Q. What branch of it?
A. The corps of engineers, under the Corps of Engineers.
Q. Just what is the scope of your duty now?
A. I am in local charge of the improvements being made by the War Department on the St. Mary's River and the general superintendent of St. Mary's Falls Canal.
Q. How long have you held that position?
A. Three years, about.
Q. Are you a graduate of any college?
A. Yes, sir.
Q. What college?
A. The University of Michigan.
Q. What degree?
A. Bachelor of Science and Civil Engineer.
Q. What year?
A. 1890 and 1894.
Q. I wish you would state briefly what experience you have had since you left college?
A. As assistant on the improvements of St. Mary's River from 1890 to 1897, inclusive; precise measurements in Texas, 1898; surveys and discharge observations for the Lake Survey, 1898 to 1903; assistant on the St. Mary's River improvement, 1903 to 1905; secretary of the American Section International Waterways Commission, 1905 and 1906; assistant St. Mary's River improvements, 1906 to date.
Q. Now, just what connection have you had with hydraulic measurements of the Great Lakes, a little more in detail?
A. I was in local charge of the measurements of the discharge of the St. Clair River.
Q. When?

A. From 1898 to 1902.

Q. And prior to that?

A. In 1896 I assisted in measurements of the St. Mary's River, and in some hydraulic studies in connection with those measurements.

Q. And after that time have you given—

A. I think that covers it.

Q. That covers it, your hydraulic work.

A. That is the hydraulic work, yes.

Q. What work did you have to do on the International Waterways Commission?

A. The ordinary executive work of the secretary of the American Section, and such hydraulic studies as were made during the time of my holding that position were under my local supervision. Those studies included the effect of regulation works on Lake Erie. I think that is as far as I need to—

Q. Now, speaking of these hydraulic measurements, particularly those relating to the discharge, the quantity of water that is discharged through the St. Clair River, I think you said you had to do at one time with those measurements?

A. Yes, sir.

Q. I wish you would tell us how those are made.

A. The instruments used to measure the actual velocity of the water passing a given section were current meters of the Haskell type. By measuring the velocity in each of several points in a cross-section, and in multiplying the resultnig velocity by the cross-section of the water in that section, gave the amount of water flowing past that partial section of the river, and the summation of these partial discharges gave the total discharge for the conditions under which the observations were made.

Q. Now, in determining the relation which the elevation of the lake has to the quantity of water which is discharged through the river, is there any set of observations made, any other?

A. Yes, sir.

Q. That you have to make observations—

A. On the St. Clair River?

Q. Yes.

A. Yes, sir; there have been some observations made since those of which I had local charge.

Q. I mean, suppose the thing which we wish to determine is the relation which the quantity of water which is dis-

charged through the river bears to the elevation of Lake Huron—

A. Yes.

Q. —what other observations are made to be used in connection with those observations, so you can—

A. I do not know that I can give the dates correctly; I know the work has been carried on since I left. That is a matter of record.

Q. Well, I mean, you take the—you determine the elevation of the lake at a certain fixed time—did you—or how did you determine that?

A. By precise levels run from the tidal waters to the various points on the great lakes, the elevation of these several points, with respect to mean sea level is determined. These points of which the elevation has been determined are called bench marks. By the use of a leveling instrument the difference of elevation between this bench mark and a point to be used in measuring the height of the water surface is determined. This gives, then, the elevation of the point used in making the water level observations. The distance of the water surface at any instant above or below this mark so set, and the elevation of which has been so determined, gives the deduced elevation of the water surface at that moment.

Q. Now, knowing the elevation of the lake at different times, and knowing the quantity of water which is discharged at different times, how do you proceed to determine the relation which the one bears to the other, the method of that?

A. It is found that in general the discharge is greater as the elevation of the lake from which the discharge is coming is increased, and the relation—

Q. If you will pardon me for interrupting, if you had no measurements at all, made no measurements at all, is there any principle which would be applicable in determining the relation the quantity of water which went through the river would bear to the height of the lake, the elevation of the lake?

A. You mean by "no measurements at all," do you mean the measurements of the current velocity?

Q. Measurements of current velocity, yes.

A. An approximate idea could be obtained from measurements of the characteristics of the river, that is, the cross-sectional areas at various points, and then by analogy the probable effect for that particular stream obtained.

Q. Well, go ahead with your description of your method.

A. Where did I leave off?

(Answer read, as follows:

"It is found that in general the discharge is greater as the elevation of the lake from which the discharge is coming is increased.")

A. That is, a relation exists between the elevation of the water surface in the lake above and the discharge of the river. This relation of the discharge to the elevation is expressed as an equation in which the discharge is given as a certain amount at a given elevation of the lake, and increasing a certain amount for each foot of rise in the lake.

Q. Through how many outlets does the water flow out of Lakes Michigan and Huron, so far as you know, Mr. Sabin, or so far as is known?

A. One.

Q. What is that?

A. The St. Clair River.

Q. And in addition to that, of course, there is the quantity that is diverted here in Chicago?

A. Yes, sir.

Q. Through the Drainage Canal?

A. I was speaking of it, naturally.

Q. You are speaking of the natural outlets. What is the effect of the diversion of a given quantity of water from Lake Michigan at Chicago upon the quantity of water which is discharged through the St. Clair River?

A. If a new outlet, an artificial outlet, is made in the lake, and no change is made in the natural outlet, the amount of water leaving the lake is greater at first than it would have been without the artificial outlet. The effect of this diversion through the artificial outlet will be to lower the water surface of Lake Michigan, until it is at such a level that the amount of water flowing in the natural outlet, plus the flow in the artificial outlet, is equal to what it would have been through the natural outlet alone, had no artificial outlet been made.

Q. So that, all other conditions remaining the same, is it or is it not impossible to divert a certain given quantity of water from Lake Michigan at Chicago, without affecting the level of the lake?

A. No, sir, it is not possible, if all other conditions remain the same.

Q. Are there any of the other factors which enter into the determination of the level of the lake, which would be modified by the diversion of the water at Chicago? I am speaking of precipitation, evaporation and those things?

A. No, it would have no effect on such natural phenomena.

Q. What are the elements, Mr. Sabin, that enter into the determination of the lake elevation?

A. Referring to some particular lake?

Q. Well, take Lakes Michigan and Huron.

A. The inflow from the lake above—the outflow through the outlet—and the rainfall on the lake surface, the evaporation from the lake surface and the run-off of the land area.

Q. I assume that you limit your answer to the natural state of the lake without any artificial modifications?

A. Yes.

Q. By the creation of any artificial outflow?

A. Yes, sir.

Q. If there was such an artificial outflow, that would be an additional factor which would have its effect?

A. Yes, I said the outflow through the outlet, and if another outlet were made that would make that plural.

Q. Certainly. Now, assume that the water is taken out from the lake at Chicago, and the result of the taking out of that water is, as you have said, to lower the level of the lake, so that the level of the lake is lower at a point 10 or 15 miles off the shore, what would be the fact with reference to the lowering of the level of the lake at other points and in the harbors and channels of the entire lake?

A. The mean level would be lowered the same amount throughout Lakes Michigan and Huron.

Q. That would be true with the level at the head of the St. Clair River, would it?

A. Yes, sir.

Q. Now, we are using the term "lowering," and you speak of lowering the level of the lakes. When you say that the diversion of the water through an artificial outlet at Chicago would be to lower the level, do you mean that that would be the absolute result; that is, that the level of the lake would as a matter of fact of necessity be lower than it was before the water was diverted, or do you use the term as if you meant lowering effect?

A. If other natural conditions remained the same after the opening of an artificial outlet as before, it would mean an actual lowering. The other factors, however, regulating the level of the lake might be such as to cause for a limited period an actual rise of the surface after the diversion was made.

Q. Well, for example, what?

A. For example, if through the artificial outlet a discharge of 10,000 cubic feet a second were taken, beginning at

some particular instant, and at that time the natural conditions changed so that the inflow from the drainage basin, we will say, is more than 10,000 cubic feet a second greater than it was before, under those conditions the water level would actually rise after the diversion was made, temporarily.

Q. Well, supposing we take this case, to fix what we mean by the definition of lowering: suppose it was possible for us, instead of having one set of Great Lakes, to have two sets; suppose we had two globes like this, identical in every respect, with the exception that for a given year on one of the globes no water was diverted at Chicago, and on the other of the globes a certain definite quantity was diverted at Chicago, what would be the effect of the level of the lake on the one globe as compared with the other?

A. The level of Lake Michigan on the one globe having the diversion would be lower than that on Lake Michigan on the other globe.

Q. In accordance with the amount that was diverted?

A. Yes, sir.

Q. Does that represent fairly what we mean by the term "lowering" as we speak of it in this connection?

A. I think that is a good illustration of it.

Q. I want to get it clearly here in the record because it is a term we use right along in the testimony. Can you give another illustration that would show it any more clearly?

A. Only perhaps by bringing it down to smaller areas, it may be perhaps more easily grasped. If we have a small pond with a certain outlet and a certain inlet, the outflow and inflow being so regulated that that pond remains at a constant level. If you now enlarge the outlet or make a new one, so that the amount of water flowing out is temporarily greater than it was before, while the amount flowing in remains the same, the level of the pond will fall. And to complete the illustration, when it has fallen euough so that the amount of water flowing out by the first outlet is decreased by the amount flowing out by the second or new outlet, the equilibrium will again have been established and the pond will be found at a lower level.

Q. Take now the case of Lakes Michigan and Huron, and the proposed diversion of the water here at Chicago. What is the fact with reference to the amount of water which will ultimately go out through the St. Clair River as compared with what would have gone out at that time if there had not been the diversion of the water at Chicago?

A. After the equilibrium disturbed by this new outlet has

again been assumed, the amount flowing out of the St. Clair River would be less than under the first supposition by the amount of the diversion.

Q. That is the ultimate effect?

A. Yes, sir.

Q. You use, I assume, in connection with your testimony in this matter, a term "net supply," and so that we may understand what is meant by that as it is used, I will ask you what you mean by net supply?

A. The net supply to a given lake I consider to mean the inflow to the lake from all sources less the abstraction of water from the lake from all sources, except the flow discharged out of its outlets or inlets.

Q. You say the quantity of water which is in Lakes Michigan and Huron—and in this examination when we speak of Lake Michigan I assume that Lakes Michigan and Huron are, so far as elevation is concerned, one about the same as the other, is that correct?

A. They are, yes, sir.

Q. So that it is proper when we speak of Lake Michigan to assume that it naturally applies to the whole?

A. We call it Lakes Michigan-Huron.

Q. Now, you say the quantity of water in Lakes Michigan and Huron is determined by rainfall, evaporation, absorption, the discharge through the St. Clair River and the inflow from the St. Mary's River: is there any one of those factors that enter into the determination of how much water there is in the lake which in itself is modified or affected by any diversion of the water at Chicago?

A. You mentioned the outflow of the St. Clair River; that is affected.

Q. Any except that?

A. No, none other to an appreciable extent.

Q. Is there any factor which determines the amount of water which comes into a lake which to any appreciable amount is itself affected by the diversion of the water at Chicago?

A. No, except for the amount of water which may be intercepted by the channel carrying this diversion. I mean the flow, for instance, of the Chicago River, which would have reached the lake, may under the new conditions be intercepted and go through the river channel.

Q. That is, it would make it that much less?

A. Yes, sir.

Q. It would diminish the quantity that came in?

A. Yes, sir.

Q. Is there any other factor which goes into the determination of that which you can conceive would be affected in any way at all?

A. No, sir, no appreciable effect.

Q. Is there any conceivable source of water coming into the lake which would be appreciably affected?

A. Not to my mind.

Q. Which in itself would be appreciably affected by the taking of water out at Chicago?

A. Not to my mind.

Q. Now, there have been presented already in the taking of the testimony in this case, certain charts or plats which have been marked Government's Exhibits 1, 2, 3 and 4; now, on those maps or charts certain observations have been platted. Did you have anything to do with the making of any of the observations that are platted on any one of those charts?

A. I had something to do with the observations taken on the St. Clair River in 1899, 1900, 1901 and 1902.

Q. Now, I wish you would tell us just how those observations are made, with particular reference to the manner in which the record of them is kept; who makes the record and how is it kept? Take a given observation, for instance, what is the system about making a record of that?

A. That is rather a long story. Those instruments are read in the field by an observer. Some of that work was done by myself personally, and sometimes it was done by an assistant, and the observation of the number of revolutions of the meter wheel in a certain length of time, as 100 seconds, is recorded in the book—in the note book.

Q. Is that note book kept?

A. That note book is preserved as a part of the records. By what are called rating observations, the meaning of a certain number of revolutions per second of the meter wheel for a given meter is determined, by methods familiar to all engineers. I suppose it is not necessary to go into it in reply to this question.

Q. Well, this is a law suit, with lawyers and judges; I guess you will have to go into it, Mr. Sabin. What I want, and you can be brief so we can get that point, is, we platted here certain observations and these observations are taken from records, of course, and they are official records, I assume?

A. Yes, sir.

Q. Made by government employes in the discharge of their duties as such employes, is that right?

A. Of the Lake Survey, yes, sir.

Q. And the record of those observations is kept at the office there at Detroit?

A. At the office of the United States Lake Survey.

Q. As a part of the records of the office?

A. As a part of the records of the office.

Q. And those records show the quantity of water which passes a given point at a given time, is that correct? What I want to find out is just what is platted there.

A. This plat is composed of points, each one of which is the mean of several observations of the discharge of the St. Clair River. The discharge is platted on this plat with respect to the elevation of Lake Huron. A line has been drawn on it which shows approximately the apparent change in discharge for a given change in level. That is what we call a discharge curve or a discharge line, and having the increment of discharge from such a plat, or from the equation of the line, the effect of any change in level of the lake upon the discharge may be determined.

Q. What does that diagonal line drawn across there show?

A. It purports to be a line which is the straight line most nearly according with the observations as platted.

Thereupon a recess was taken to 2 o'clock p. m. of the same day, Wednesday, April 21, 1909.

Wednesday, April 21, 1909, 2 o'clock p. m.

Parties met pursuant to adjournment.

LOUIS C. SABIN resumed the stand and testified further as follows:

Mr. Wilkerson: Q. Referring now to these plats which you had before you this morning, Mr. Sabin, I wish you would take the one that is marked Exhibit No. 1, which relates to the discharge through the St. Clair River, I think, does it not?

A. Yes, sir.

Q. I wish you would tell us whether you have seen that plat before and what you have done in connection with it?

A. I have seen a copy of it before and have examined it; I did not prepare it.

Q. What do you say as to whether that line that expresses the relation between the lake level and the volume of discharge is correctly drawn?

A. I have not checked over the platting of these points; with those points as platted, I should say that the line drawn through them fairly represents them.

Q. Assuming that that line is correctly drawn, what have you to say with reference to what is there denominated the "increment"?

A. The increment is the change of outflow for a foot change in stage; as given here is 23,800 cubic feet per second.

Q. On the basis of that chart, what would be the lowering of Lakes Michigan and Huron in inches for a diversion of 10,000 cubic feet at Chicago?

A. It would be 10,000 cubic feet divided by the increment, 23,800 cubic feet, multiplied by 12, which gives about five inches.

Q. You mean divided by 12. Is that what you said?

A. No, multiplied by 12.

Q. Multiplied by 12?

A. Yes, sir.

Q. In your opinion, how exact is that statement?

A. From my general knowledge of the discharge increment of the St. Clair River, is that what you mean?

Q. Yes.

A. I think that five inches would be a minimum amount; but I should expect it to be not less than five inches, and perhaps considerably more.

Q. Explain why do you say that?

A. Because in the work that I have done with a portion of these data, I have been led to the conclusion that the increment, when referred to Lake Huron alone, was somewhat smaller than the one that is given here.

Q. The smaller the increment, the greater the change in lake elevation, corresponding to the loss in outflow. Is that correct?

A. Yes.

Q. Why is that true?

A. A loss in depth of one foot makes a given change in outflow, which is called the increment. Now, if that increment is small, then a given diversion is a larger proportion of that increment, and therefore a larger proportion of the foot which the increment represents.

Q. Now I direct your attention to this fact, Mr. Sabin: you speak of the increment which is used as a basis of those

calculations as being probably larger than the true increment; and I direct your attention also to the fact that Mr. Wheeler, in his computation on the chart, had to recompute it, the points as there platted, and had a figure for increment which differed slightly from the increment which is there used. Can you explain to us why it is in different calculations with reference to these, there is this slight variation in the increment which is used?

A. Yes, because on the St. Clair River, the discharge at any time is a function of two quantities; the elevation of Lake Huron and the elevation of Lake Erie; and it therefore requires a larger number of observations to obtain it with the same accuracy than in the case of those streams where they have but one variable affecting the result. And the nature of the effect of Erie and Huron is such that a change, an assumed change given in deriving the equation, an assumed change in one will have an effect upon the resulting change in the other, in the effect of the other, so that, to illustrate: under certain conditions of levels in Lakes Huron and Erie, we have a certain discharge. Now, suppose that Lake Huron goes up an inch, Lake Erie remaining the same; the discharge will be increased by a certain amount.

Q. Do you mean Lake Erie or Lake St. Clair?

A. Yell, I am speaking of Lake Erie rather than Lake St. Clair, for the reason that Lake St. Clair's level is practically controlled by the levels of Lake Erie and Lake Huron. And I thought it better, therefore, in this illustration, to go to the lake that had this regulating effect.

Q. Excuse my interruption; go on with the answer.

A. As I was saying, this raise of an inch in Lake Huron would have a certain effect. Now, at another time, with Lake Huron at the same elevation, if Lake Erie went down an inch, that would also have the effect of increasing the discharge. When you have a series of observations, you have various variations in the surface of both Lake Huron and Lake Erie, but as a lowering of Lake Erie has a smaller effect than a raising of Lake Huron, in the discharge on any given day, you may mistake for the effect of a raise in Lake Erie a lowering in Lake Huron; and the variation in increment of Lake Huron, as gotten by different computers, has this variation due to this cause. And this is one of the highest ones; that is this increment shown on this plate of 23,820, is one of the highest increments. During practically the first year or two of my observations on the St. Clair River, I de-

duced an equation which showed that the increment was about 19,000, instead of 23,820.

Q. That is from a different series of observations?

A. No, that series of observation is also included in here.

Q. But other observations are added?

A. Are also added to those. I should think that the truth lay between probably 19,000 and 23,820.

Q. Without regard to the precise quantity which is to be put down as representing this increment, what do you say as to the absolute fact as to the effect of diminishing the quantity of water which flows out through the St. Clair River upon the level of Lakes Michigan and Huron; I say, without regard to the precise accuracy of the increment?

A. What effect has the flow?

Q. What do you say as to the absolute fact as to the diminishing of the quantity of water which goes out through the St. Clair River upon the level of Lakes Michigan and Huron, the relation between those two?

A. Well, certainly an increase in discharge of the St. Clair River would have a tendency to lower the level of Lake Michigan. Is that your question?

Q. My question is as to the absolute fact as to the relation between the level of Lakes Michigan and Huron and the discharge from the St. Clair River, as to there being such a relation.

A. Yes, there is no doubt at all about that.

Q. I mean as to the absolute fact?

A. No, sir, no doubt at all about that.

Q. And as to the amount of the change, do you think the truth is some place between the low increment, to which you have referred here, and the higher increment which is used on the charts that have been produced by the government?

A. Yes.

Q. And if the lower increment be used, would the effect be greater or less; that is, would the lowering of the level be greater or less?

A. The effect of a given diversion would be greater with a small increment.

Q. Having in mind your own deductions and your own experience, what would you say as to the limits between which the effect of a diversion of 10,000 cubic feet at Chicago would fall, in inches?

A. Between five inches and seven and one-half inches.

Q. Can you give us any information as to the percentage, as to what percentage of the lowering in Lake Michigan the

water in St. Mary's River at the foot of the locks would be lowered?

A. I can't give a definite answer to that question for the conditions prevailing at present, because last August the conditions of outflow of the St. Mary's River were quite seriously disturbed by the opening of a new channel. Previous to about 1890 the work that had been done in the improvement of the lower St. Mary's River was quite small. And I have had occasion to go into that question for that period, and the effect for that period, up to 1890, would be about 47 per cent. That is, that a change in the elevation of Lake Huron would change the elevation of the St. Mary's River at the foot of the locks 47 per cent. as much; that is, one foot of Lake Huron would change the St. Mary's River .47 of a foot. Since that time, due to the improvements in the St. Mary's River, the slope, which previous to that time had had a mean value of about 2.1 feet, has been reduced by from a foot to a foot and two-tenths, I should say, by the new channels opened and the improvements in the channels, and the slope being less for a given elevation of Lake Huron, and a given discharge from Lake Superior, the effect would be greater; how much greater it is difficult to say, bearing in mind that 47 per cent. was the figure before 1890, and that the slope has been changed over a foot; I should say that perhaps 60 to 75 per cent. of the loss would be felt.

Q. Within what limits, then, if you are going to get the effect, could you put the fact as to that, so as to be absolutely sure that you were within the truth?

A. There would be no question in my mind about the lower limit being above 47, and the upper limit would be below 100; and I would not care to go any further.

Q. The point I wanted to bring out was, would there be any doubt, is there any doubt that there is some substantial effect, first?

A. No. Those limits give substantially the effect; 47 per cent. is the lower and 100 the higher; that is not absurd.

Q. And as to the lower limit, you would say that was not open to doubt?

A. No, not open to doubt, any more than any other engineering data are.

Q. I suppose this is true, if I may put the question in this form, isn't it, Mr. Sabin, that without regard to the precise amount of the effect, there are elementary laws or

principles which control, in a situation of that kind, which make it absolutely certain that there would be some effect?

A. Yes, with a knowledge of the natural conditions existing; there is no doubt of it.

Q. What is the mean fall at the present time between the water at the foot of the lock and Lake Huron?

A. The recent improvements have not been completed long enough to determine that. The mean fall for the seven months of navigation from 1871 to 1890 was 2.1 feet. That fall is affected by the elevation of Lake Superior, or rather by the discharge of the St. Mary's River and by the elevation of Lake Huron; and it varies considerably. Taking the mean for seven months, considering only the mean for each year for the seven months of navigation from May to November, it has varied from a foot and a half to 2.9 feet, roughly.

Q. You have given us your answer now with reference to the lowering of the water at the foot of the locks. Are you prepared to make any statement as to the effect at the critical points in the river?

A. Only within rather wide limits.

Q. Well, first, as to there being some substantial effect?

A. There would be substantial effects, and the character of the river is such that the percentage of a given change on Lake Huron, the percentage of that effect, starting out, whatever it may be at the locks, would increase from the locks down until it became 100 per cent. at the mouth of the river.

Q. So if 47 per cent. were taken as the lowest limit at the locks, the effect at those different critical points would be expressed by percentages larger than that?

A. Yes.

Q. Increasing as you went down the river?

A. Yes.

Q. Which would in the case of most of them be in excess of 50 per cent.?

A. Yes.

Q. And as to those that were further down the river, very considerably in excess of that?

Question objected to by counsel for the defendant, on the ground the counsel is leading the witness and testifying.

A. A very considerable extent.

Q. If Lakes Huron and Michigan are lowered a known

amount, and Lake Erie a known amount, what would be the effect in the Detroit River, Lake St. Clair and the St. Clair River?

A. They will also be lowered.

Q. Can you make any statement as to the amount, or have you given consideration to that?

A. I should expect that the level of St. Clair would be affected by practically the mean of the two lowerings; that is, the mean of the lowering for Lakes Michigan and Huron, and the lowering of Lake Erie.

Q. What would be the effect of the diversion of water from the lake at Chicago upon the outflow of the Niagara and St. Lawrence Rivers, and why?

A. It will decrease the outflow of those rivers by the amount diverted at the Chicago Drainage Canal, practically undiminished.

Q. Now, with reference to these three other charts that I showed you this morning, Mr. Sabin, I wish you would take each one of those charts and tell us what examination you have made of them; what each one represents, and whether in your opinion the result as stated in the form of that scale at the left hand side is correct?

Mr. Williams: He is not testifying now to the correctness of the observations or the correctness of the platting of them.

Mr. Wilkerson: Q. I understand, with the exception of the observations on Lake St. Clair, you did not make any of the observations that are represented on the plat?

A. No, sir.

Q. You have testified about the only one of the plats as to which you made observations?

A. Yes, sir.

Q. As to the others you did not make the observations yourself?

A. No, sir.

Q. Nor did you plat the observations?

A. Not on this, no, sir.

Q. What you have done is as an engineer to make an examination of the methods of reaching the result. Is that what you have done?

A. Yes, sir, I have gone over that, not with respect to these plats, because I have not gone over that matter since that time, further than to see that this agreed approximately with the data which I had checked over and satisfied myself about before.

Q. Have you gone over the method which has been there used of reaching this result?

A. Yes, sir.

Q. As based upon observations of lake level and outflow?

A. Yes. That is a proper method.

Q. I wish as an engineer you would give us for the record here a brief explanation of the method that has been used on these charts.

A. Exhibit No. 2 has a number of points plotted, purporting to give the discharge measured a certain heights of water surface in the St. Lawrence River at Ogdensburg. Through these observations a line has been drawn which fairly represents the observations as plotted. This line may be used to indicate the change in discharge of the St. Lawrence River for a given change in level at Ogdensburg, or to show for a given change in discharge at Ogdensburg what the resulting change in level would be. This line shows a change of outflow for one foot change in stage, 28,870 cubic feet per second.

Q. Now, does the same general explanation which you have made with reference to that apply to the others?

A. It does.

Q. Assuming the accuracy of the observations which have been platted, and assuming the accuracy of the platting of those observations, what have you to say as to the correctness of the result which has been reached, based upon the observations as platted?

A. I think that line fairly represents the observations plotted. That is all that can be said, I think.

Q. Would you say, if the observations were correctly made, and if they are correctly platted, that the result is substanitally correct?

A. Yes, sir.

Q. And by that I refer to the result in the lowering of the lake level, as expressed there on the scale at the left of the chart?

A. That would refer to the St. Lawrence River, and the lowering of the river at Ogdensburg.

Q. That is as to that chart?

A. Yes. You said "lake." It would show the lowering of the river at Ogdensburg.

Q. I was correct in using the word "lake," with the exception of the one chart where it is in the river?

A. Yes, sir.

Q. So that, if water is diverted at Chicago, will Lake Erie be lowered?

A. Yes, sir.

Q. And what will be the effect upon the Niagara River?

A. That will also be lowered.

Q. And what about the effect on Lake Ontario?

A. That will also be lowered.

Q. Now, how much in each case?

Mr. Williams: Do you mean in percentages, or given a certain amout of diversion?

Mr. Wilkerson: I am speaking on the basis of 10,000 cubic feet per second, and I am assuming—and I ask you to correct me if I am wrong in it—that if we have the amount of the lowering for 10,000 cubic feet, for a smaller amount or a larger amount, it is proportionately smaller or greater. Is that correct?

A. It is.

Q. So we will take a diversion of 10,000 cubic feet for the purpose of shortening the record, and limit the answers to that, with the understanding that the lowering for a different diversion can be reached by taking a proportion thereof?

A. The effect on Lake Erie will be five and one-half inches, forty-six hundredths of a foot. The lowering at Ogdensburg four and one-quarter inches. That answers the question, does it not?

Q. Have you given them all?

A. Lake Erie and St. Lawrence River.

Mr. Williams: Lake Ontario you did not give.

Mr. Wilkerson: Did you give Lake Ontario?

A. Lake Ontario would be very slightly greater than the St. Lawrence River at Ogdensburg; practically the same, but very slightly greater.

Q. With regard to the accuracy of those figures, as to their being larger or smaller than what is probably the fact, what do you say about that?

A. I think that the figures for Lake Erie and Lake Ontario are very good; roughly, I should say not over half an inch in error, as given.

Q. That is for a diversion of 10,000 cubic feet?

A. That is for a diversion of 10,000 cubic feet a second.

Q. How do the recent measurements of the Niagara River agree with the measurements made by the Deep Waterways Commission in 1897 and 1898?

A. They agree quite well; when I speak of agreement, the

same conditions are not always renewed—do not always occur again.

Q. With regard to the increment of discharge?

A. I have never worked out the increment from the measurements of the Deep Waterways Board alone.

Q. How about the comparison of the recent measurements with those by Quintus in 1891 and 1892?

A. I could not testify to that.

Q. Coming back now to the St. Clair River, what is the season of navigation in the St. Clair River? I don't mean whether there may be a few boats a month, but using that word in the generally accepted meaning that is given to it?

A. Usually during January, February and March, there is very litle navigation on the St. Clair River.

Q. Now, in connection with the St. Clair River, there is what is known as ice retardation, is there?

A. Yes, sir.

Q. What do you mean by that?

A. The presence of ice in any channel cuts down the cross-section of flow and reduces the amount flowing as compared with the same conditions without ice, I should say.

Q. When does this ice effect begin?

A. It varies from—in different years. There are no accurate records that are available except for the last few years, with this exception, that a disturbance in the relative fall in St. Clair River and Detroit River indicates the presence of ice is one or the other. But I should say retardation might be of such an effect in both at the same time that no disturbance of the relative falls would be noticed, and aside from that data I say there are none that I know of, that I recall at least at the present, previous to about 1899, when the gauges were established at the head of the St. Clair River. Since that time one can infer with considerable certainty whether there were ice retardations in the St. Clair River. Have I answered the question?

(Last question read.)

A. In those last few years, there are only three which show a marked effect in December. And there is but one or two that show any marked effect in May.

Q. How long does that ice effect continue?

A. Different lengths of time in different years.

Q. How about April?

A. April, there is quite frequently an ice effect, a retarding effect from ice in April.

Q. How about May?

A. Seldom, as I said.

Q. And is some time in May as late as it is ever noticeable?

A. Yes, and I think it is never noticeable in November; usually not in December.

Q. Now, what is the effect of this ice retardation upon the level of Lakes Michigan and Huron?

A. As it holds the discharge to a lower value than it would have without the ice, it has the effect, the immediate effect, of raising the level of the lake.

Q. Is there anything in this ice effect about which you have been testifying that in any way neutralizes or overcomes the lowering tendency from the diversion of water at Chicago?

A. No, I can see that it would have no effect on that.

Q. Would it have any relation on that whatever, that is, so far as the lowering tendency of the diversion of the water at Chicago is concerned, is there any conceivable relation?

A. No, I think not.

Q. By that you mean you can see none?

A. I can see none.

Q. By that answer you mean this lowering tendency here would go on even though—

A. Yes, sir; that, I think, was in your question.

Q. —even though there was the other tendency, on account of ice in the St. Clair River? I wanted to make it clear, that is all. What information are you able to give us, Mr. Sabin, as to whether the St. Clair River is changing its regimen?

A. I don't know what it has been doing in recent years other than the reports of others. I made an investigation of it about 1900, 1902, and concluded that there was no reason to suspect that there had been any appreciable change in regimen as far back as the records went, of the depth of the channel.

Q. Well, suppose there was some small scouring, what would be the effect?

A. It would change the value of the increment of discharge for a given change in stage. The most likely effect would be that it would increase that increment; making the change in discharge for a given change in stage greater.

Q. I assume that there is some change in the regimen of the St. Clair River from time to time, at a given time, at a

given fixed time. Is there anything in that which neutralizes or overcomes in any way the lowering tendency of the diversion of water at Chicago?

A. No, it does not neutralize or overcome that lowering tendency, but may change its amount.

Q. Is or is not that a factor that is analogous to the ice effect, about which you have testified?

A. Yes, with this exception, that if such a change in regimen were made as to change the value of the increment, then the ultimate effect of a given diversion at Chicago would be different with that new increment than it is under the present conditions, with the present increment.

Q. But there would be?

A. The same tendency would be there to lower.

Q. There would be the same original diversion, which would be translated into effect on the basis of the new increment?

A. Yes, sir.

Q. Well, has there been any such change or do you think any such change possible, that would result in such a change in the increment as to materially affect the lowering tendency of the diversion at Chicago?

A. I should dislike to testify about what is going to happen, but judging from what has happened in the last 50 years, I should not expect—

Q. Assuming that the laws of nature remain constant, for the purpose of your answer, and that there is no such thing as an earthquake or other dire disturbance?

A. In the last 50 years there has been no practical change in the regimen of the upper St. Clair, so far as I know.

Q. So that, so far as that factor is concerned, could you say that increment would remain substantially unaffected from time to time?

A. I think I have practically said that.

Q. I wanted to be clear on that.

A. Yes, sir.

Q. You have given your time for a number of years pretty continuously to the study of the lakes, have you, Mr. Sabin?

A. For certain periods during the last few years, yes, not continuously.

Q. Do you know, or did you ever hear of any outflow from Lakes Michigan and Huron, except through the St. Clair River and what water is diverted at Chicago, substantial diversion?

A. No, sir.

Q. Well, what other diversions do you know of? Is there any other?

A. Nothing, I think, that could be called a diversion, nothing that could be called an outflow.

Q. Anything that would have an appreciable effect upon the quantity of water in the lake?

A. Well, the effects of rainfall and evaporation, but nothing in the nature of outflow.

Q. Outflow?

A. Yes.

Q. I was speaking of the outflow, that is, of the ways in which water gets out of the lake. There is some water, it is said, seeps into the lake, and it has been assumed, or I suppose it may be assumed, that some water comes in in the shape of subterranean streams or springs. Now, what would be the relation of that condition to the level of the lake?

A. I do not think, in the first place, that such an assumption is warranted.

Q. Well, give us your view of that. I would like to have your opinion, based upon your experience and your study of lake conditions, with reference to that.

A. I can see no reason for anticipating that there is any large flow into the lake or out of the lake by underground streams. If there were such streams its effect upon the ultimate effect of the diversion would be practically nil.

Q. From the very nature of things where does most of the water that gets into the lake come from?

A. It comes from streams flowing in along on the surface, streams flowing into the lake and on the surface of the ground, the rainfall, representing the rainfall on the drainage basin, and there should be added to that, perhaps, the rainfall on the lake surface, if that is not included.

Q. Well, if there was some water coming into the lake through subterranean streams, is there anything in that which there is not in the water which comes in on the surface which would counteract or neutralize the lowering tendency of the diversion of water at Chicago?

A. No, sir; nothing.

Q. There has been some reference, Mr. Sabin—I don't know whether it has been in your testimony or not, but in connection with this matter—to inconsistencies in the outflow value of the St. Clair, Niagara and St. Lawrence Rivers;

what do you know about that, and as to there being any that cannot be accounted for by ice retardation?

A. There are no inconsistencies so far as I am aware of that cannot be accounted for.

Q. Is that the result of your observation and study of this matter?

A. Yes, sir.

Q. Have you had occasion in your investigation of these questions to give consideration to data regarding evaporation and precipitation?

A. I have done a little work along that line, not very much.

Q. Have you any information as to the manner in which these statistics are collected, as to the number of observations, and as to their frequency, as to the amount of territory which is covered?

A. Yes, sir; I think that is all a matter of record, as those observations are made by the weather bureau, the observations for precipitation.

Q. It being a matter of record, it is a matter which has been brought to your attention?

A. Yes, sir.

Q. And which you have considered?

A. Yes, sir.

Q. Have you given consideration to them with a view to forming an opinion as to the degree of accuracy with which they indicate the given result?

A. In a general way, yes.

Q. Now, having that in mind, what would be your view of the propriety of using those particular data in a computation, the attempt of which was to detect the presence of absence of the effect which was produced on the lakes by the diversion of water at Chicago since 1900?

A. To my mind the character of the data which we have as to rainfall, and particularly as to evaporation, is such that it does not compare with the accuracy with which we know the outflow of the lakes, and the effect of a diversion of water can be obtained from our knowledge of the law of outflow. I should think it would be very poor engineering to attempt to combat information obtained from outflow observations with a computation which rested upon the observations for evaporation and rainfall. Is that what you wanted?

Q. Yes. Now go along that line a little further, and compare for us, if you will, the accuracy with which the outflow

observations are made and the accuracy with which these statistics about evaporation and precipitation are obtained. Let me add to that question: is there anything in the very nature of things which makes it possible to get a high degree of accuracy in one case which you cannot, from the nature of things, get in the other?

A. I can only answer that in a general way; that the information regarding the rainfall is—that the observations at any given place are subject to a considerable error, and the stations are not sufficiently distributed to give an accurate result, accurate knowledge of the amount of water falling on the lake basins, and the information regarding evaporation is in still worse shape.

Q. Now, as to those observations with regards to outflow, how about the frequency of the observations and the amount of space that is covered and their limits that make possible or impossible the obtaining of a high degree of accuracy?

A. I think that the outflow at any given time, at any given lake stage, can be determined with a reasonable number of observations within something like 5 per cent., I should say. The determination of the law of discharge, as related to the lake level, cannot be determined with that accuracy, but the errors in these determinations are much smaller, in my opinion, than those which attach to the data concerning rainfall and evaporation.

Q. I think you said a little farther back in your testimony, Mr. Sabin, that at the outside you regarded these scales expressing the loss in level, loss in lake level, at a diversion of 10,000 cubic feet at Chicago, as within half an inch?

A. For Lake Erie and Lake Ontario?

Q. Yes.

A. Yes, sir.

Q. As to Lakes Huron and Michigan, you may state the figures, from your knowledge and information, so formed.

A. I should think the upper limit was perhaps seven and one-half inches.

Q. Why do you say that maximum figure is seven and one-half, Mr. Sabin?

A. That is merely a matter of judgment, from my investigation of the data.

Q. Have you had occasion to give consideration to the subject of navigation of the lakes, the use of boats and vessels on the lakes?

A. Yes, sir.

Q. To what extent have you had occasion to study and observe that?

A. I have been in charge, local charge, of the locks at Sault Ste. Marie, and I have been more or less familiar with the operations of the shipping interests.

Q. Very well. Now, bearing in mind the fact that the lakes change in their stage from year to year, and that at times the lake surface is disturbed on account of wind and storm, I will put to you the question whether or not the lowering of the level of Lakes Michigan and Huron to the extent of two or three or four inches has any appreciable or material effect upon navigation in the harbors and channels of the lakes?

Mr. Williams: I object to that, to the form, as calling for a conclusion and not for the facts—

Mr. Wilkerson: I will accept the amendment of counsel, and have you give us the fact as to the effect of the lowering of the lake by two or three or four inches, upon nagivation.

A. It requires the vessels to load accordingly. There are certain places in the lake system where certain vessels are loading as heavily as the water level will permit.

Q. As to the number of vessels which could carry heavier loads than they do, if these channels or critical points in the lake were deeper, what have you to say about that?

A. In 1907 there were 360 boats passing St. Mary's Falls Canal that were capable of loading to 19 feet or over. The amount of freight carried through the canal by these boats in 1907 was about 49,000,000 tons.

Q. Now, what determines the depth to which those large boats can be loaded?

A. Those boats which come from or go to Lake Superior are governed by the amount of water at the lower end of the Poe Lock.

Q. Have the levels of Lakes Michigan and Huron anything to do with that?

A. Yes, sir; as already testified to under another question, the effect of Lakes Michigan and Huron lowering is felt at that point.

Q. Have you any figures which show the number of boats that are capable of loading to 20 and 21 feet, based upon your observations and study?

A. Of the boats passing the St. Mary's Falls Canal in 1907, there were 227 that were capable of loading to 20 feet and 133 capable of loading to 21 feet or over.

Q. How deep could they load at that time?

A. The available draft varied from about—it was about 19 feet 9 inches, and from that—I think from memory it was 19 feet 6 to 20 feet, and about 43,000,000 tons of freight were carried in boats which were limited by the draft in the lower levels of the locks.

Q. You send out instructions or information as to the depth to which boats can load?

A. Yes, sir; and we post that information for the information of vessel masters and shippers.

Q. How much do you allow between the bottom of the boat, do you allow any space in there?

A. No, not ordinarily. The water levels vary from day to day, and we try to give in those notices the mean drafts that they will find on the Poe Lock floor.

Q. Well, suppose the level of the lock there, the level of the water there at the canal is lowered, what effect has that on the load which the boat can carry?

A. That depends upon the size of the boat.

Q. Have you any figures there that would indicate the effect of this lowering on commerce as it is now carried on?

A. Yes.

Q. If you have that I will ask you to refer to your notes and give us the exact figures on that. Are those figures on the basis of the lowering of an inch?

A. Yes.

Q. All right. Assume, now, the level of the lake is lowered an inch, so that you can draw that much water in the locks.

A. For the larger class of boats an inch of draft means from 80 to 85 tons of freight, so that from an inch change in the draft the load of the boat would be changed by 80 or 85 tons.

Q. Have you figured out what the loss of an inch would be to commerce on the basis as it is now carried on, and taking into consideration the boats that are now engaged in this trade?

A. No, I don't remember that I have; I think not.

Q. I think, though, you have given us the data from which we could make the computation ourselves, haven't you? You have given the number of boats and you have given the loss in tonnage?

A. I think the question of the loss of tonnage, I have given that for each inch of change in draft.

Q. So all we need to know, then, would be the number of trips?

A. The number of trips?

Q. About how many trips would one of those big boats make in a season?

A. I think about 20 trips.

Mr. Williams: You are testifying now from your own knowledge, and not from something that somebody has told you or reported.

Mr. Wilkerson: Well, he is up at the Sault.

A. Yes, from information as collected at the lock.

Mr. Williams: Q. It is your personal information and not information given to you by bulletins?

A. No, it is not given to me by bulletins, but it is not what I have personally collected.

Mr. Wilkerson: Q. Is it information which is collected from a record which is made under your supervision?

A. Yes, sir.

Mr. Williams: I object to his testifying from it.

Mr. Wilkerson: Q. Answer the question.

Mr. Williams: On the ground that it does not purport to be information which is the result of his own personal information, but as a result of work done by others.

Mr. Wilkerson: Q. How are those records compiled, Mr. Sabin?

A. Each vessel that passes the locks is reported by the captain as to her tonnage, freight carried, ports of hail and destination, and this information is kept and tabulated in the office.

Q. Can a boat go through the lock without giving that report?

A. No, sir; not ordinarily. I think we may lose two or three in a season until they come on the second trip.

Q. What is done with those reports?

A. The information is tabulated and published in the form of statistical reports of lake commerce, covering in considerable detail the amount of freight carried, the number of boats of different sizes and so forth.

Q. Have you that report with you?

A. That is a copy of it. (Handing document to counsel.)

Mr. Williams: Instead of asking the witness the questions you have, I haven't any objection to your introducing that report that he is testifying from.

Mr. Wilkerson: Very well.

Q. What you have stated with reference to the number of vessels going through is based on this report, is it, Mr. Sabin?

A. No, it could not be obtained from that report, but it was obtained from the data from which that report was obtained.

Q. I see.

A. The information which I gave was based upon the records for the entire season of 1907.

Q. Yes.

A. And they are voluminous records.

Q. Could you get from this report which you have produced the facts with reference to the number of times any given vessel made a trip?

A. No, sir.

Q. You would have to go to the—

A. Yes, sir.

Q. —reports from which this book is compiled?

A. Yes.

Mr. Wilkerson: This book which Mr. Sabin has produced may be marked for identification as an exhibit of this date, so that we will have this book identified in case that either side wants to refer to it or offer it hereafter. It may be, when we get through, we will not want to encumber the record with it, so I will not offer it in evidence, thinking perhaps maybe we may be able to make some agreement as to what it shows.

Mr. Williams: Is that the 1908 report or the 1907?

A. 1907.

Mr. Wilkerson: Mark it as Statistical Report of Lake Commerce Exhibit of this date.

Whereupon said book was marked as Statistical Report of Lake Commerce of 4/21/09.

Mr. Williams: Does that report show the tonnage of the vessels, or the number of tons carried on their different trips?

A. Both, in a collective way.

Q. In that report?

A. Yes, sir; not the individual instances.

Mr Wilkerson: What do you know, Mr. Sabin, as to the dimensions of the largest freight carriers now engaged in commerce traversing the waters below Lake Superior?

A. The L. S. De Graff has a length of 605¼ feet over all, and 60 feet beam. She has carried a cargo of 13,638 tons.

Q. Any considerable number of those large boats engaged in commerce now?

A. Yes, a great many.

Q. What is the tendency in the construction of those boats?

A. Most of the boats that are being built now are what may be called the larger class, although not all of them by any means of that size. The tendency is to increase the average size of the boats. That is a part of the data in that report that you have just made an exhibit.

Q. What about the tendency to build boats so large that they cannot be loaded to the limit now, and which would be affected in the load which they would carry by the lowering of the water in these channels?

A. We have just now an available draft of 18 feet 3 inches over the Poe Lock, through the Poe Lock, and in 1907 there were 360 boats that could draw 19 feet or more. Those 360 boats carried 49,000,000 tons of freight.

Mr. Williams: You testified to that before, Mr. Sabin.

Mr. Wilkerson: Yes.

A. The question was practically repeated.

Mr. Williams: He asked you about the tendency now.

Mr. Wilkerson: Q. I say, is it the tendency to build boats of that class now, so that they are becoming more and more numerous all the time?

A. Yes.

Q. And they cannot be loaded to the limit because of the condition of the lakes at these critical points?

A. Yes, sir.

Q. And the boats which would be affected by a lowering of from an inch, the lowering of the lake?

A. Yes, sir.

Mr. Wilkerson: You may cross-examine Mr. Sabin. It may be that I have overlooked a question. If so, I will put it in re-direct as though it was direct examination.

Mr. Williams: That is all right.

Cross-Examination by Mr. Williams.

Q. Mr. Sabin, are you familiar with this bulletin No. 18 of the War Department Corps of Engineers? (Handing book to witness.)

A. No, I am not familiar with it; I have seen it.

Q. On page 259 of that bulletin, referring to the Detroit River, occurs this statement: "During the lowest water of the season of 1907, except for temporary storms, a draft of 19 feet could be carried through the river, the place of lowest depth being at Lime Kiln Crossing, near the mouth of the river." Do you know how long that condition has existed?

A. No, sir.

Q. That is a greater depth by how much than that provided for during the year 1907 at the Poe lock?

A. The depth of water in the Poe lock in 1907 varied from 19.5 to 20.8.

Q. During the entire year?

A. During the season of navigation, April to December.

Q. What was the situation there during the year 1908, what was the depths?

A. I haven't those figures with me.

Q. What is the present available depth?

A. Eighteen feet three inches.

Q. How long has that depth been the available depth?

A. About ten days or two weeks.

Q. Taking up the chart or plate—

Mr. Wilkerson: Will you pardon me?

Q. Do you have what is known as low water days?

A. Oh, yes.

Q. What do you mean by that?

A. The water fluctuates, not only daily, but hourly and monthly. The water level at the lower end of the lock changes from month to month as is shown on the exhibit just put in evidence or identified. The water level is usually low in April and May and high in July, August and September, at the foot of the locks, so that this 18 feet three inches probably will not hold very long.

Q. You are giving the monthly means, are you?

A. Yes, sir; I was giving the monthly means when I read them off as to the variation, those are the means of the month. Of course, that is not the maximum variation by any means.

Mr. Williams: Q. Right on this very question propounded by Mr. Wilkerson, and in answer to it, you say that the height of the water there varies sometimes hourly and sometimes daily?

A. Yes, sir.

Q. What are those variations caused by?

A. The short time variations, those rapid variations, are caused principally by barometer and wind.

Q. And how great a variation would you consider as not being unusual, resulting from such causes?

A. In how long a time?

Q. Well, say in 24 hours?

A. During the summer season about two or three inches.

Q. Have you known of variations exceeding two or three inches, occurring within a period of say 24 hours, resulting from barometric and wind causes?

A. Yes.

Q. How great a variation have you seen within that time?

A. Well, certainly six inches; I would not say how much more.

Q. Would you say that you had ever seen a greater variation than six inches?

A. No, I would not say that I had.

Q. And within how short a time have you seen a variation of six inches?

A. My recollection of the times that I have seen those fluctuations on the lower St. Marys River are not sufficiently exact for me to go into them.

Q. How near the bottom of the channel does the ship's bottom pass at the locks, ordinarily?

A. I think that that question is a little indefinite. Not ordinarily. Some of the boats drag on the bottom as they go out; some of them may have an inch under them and some may have two or three feet.

Q. Do you give any instructions to the vessel owners as to the amount of draught they may carry through the locks?

A. We give them the amount of available draught as near as we can,—the amount of water there is in the lock. We give them that information.

Q. And you supplement that information by a statement of the draught they will be permitted to load to?

A. They draw all the water there is in the lock.

Q. And there are no instructions given, then, only information as to the amount of water in the lock?

A. No, sir.

Q. Now, passing through the St. Clair River, or the Detroit River, do you know to what depth the vessels load, how near the bottom, at the critical points?

A. It is my understanding that they touch the bottom in going through. They certainly did in the St. Marys River before it was improved.

Q. You made or had charge of the observations in the St.

Clair River, which in part form the foundation for the Exhibit No. 1?

A. Yes, sir.

Q. When were those observations made?

A. In 1899, 1900, 1901 and 1902.

Q. Were those observations and the results thereof published?

A. Yes, sir.

Q. With a report by yourself in the report of the chief of engineers?

A. Yes, sir.

Q. The gauge heights and elevations of water surfaces shown in your reports published in Appendix EEE, are they subject to correction? This is 1902?

A. The water levels that are found in that report are based on the determination of elevations of bench marks made a good many years ago. In 1903 the lake survey completed a new determination of the difference in levels between these bench marks and the sea level.

Q. Well, now, then, assuming that the several gauges, heights and elevations of water surfaces mentioned in these reports are subject to correction due to a more accurate determination of bench marks by the levels known as the levels of 1903, I will ask you whether the data presented on pages 2830, 31, 32, 33, 34, 35, 36 and 37 of Appendix EEE of the annual report of the Chief of Engineers for 1902 are correct representations of your observations of the discharge on the St. Clair River as shown by these reports during the years 1899, 1900 and 1901?

A. Yes, so far as they purport to be.

Q. Will you explain what you mean by that last sentence?

A. Why, that there are some things in those tables which are not a matter of observation.

Q. For instance?

A. For instance, table No. 7, on page 2837, is one that I notice.

Q. Yes?

A. The effects of ice there are not measured effects. They are from the application of a formula.

Q. Then we will exclude table No. 7 and refer only to the first six tables, and limit the question to page 2836; that is, I think, the last page,—from 2830 to 2836, inclusive.

A. They, I believe, are a correct representation of the

data as obtained by me, and the deductions which I made from them.

Q. Now, then, would you say the same as to pages 2811 and 2812 of Appendix FFF of the annual report of the Chief of Engineers for 1903, referring to observations for the year 1902?

A. No, I don't think that I prepared that table.

Q. Were the results of your observations for the year 1902 published?

A. I think all I made were in this previous report.

Q. Now, Mr. Sabin, the data concerning which you have testified as being the results of your own observation, and shown in Appendix EEE, are those observations and the data contained in that report subject to any other corrections than those that I suggested in the former question, than the corrections due to the more accurate determinations of the bench marks?

A. No, except as appears in the report.

Q. Now, will you look at the map and the cross-section on plate 1, opposite page 5400 of Appendix III and KKK of the annual report of the Chief of Engineers for 1900, and state whether or not that plate was prepared under your direction and supervision?

A. Yes, sir, it was.

Q. And is it correct, and does it correctly represent the matters purporting to be shown thereon?

A. It was compiled from the best data available at the time.

Q. And to the best of your knowledge and belief it is as correct as could have been made from that data?

A. Yes, sir.

Q. Have you any reason to believe that the conditions existing at the time that that plate,—cross-section,—was prepared, were any different from what they are now?

A. There have probably been some slight changes along the banks.

Q. Well, confine it, then, to the time that it was prepared. Have you reason to believe that any of the facts purporting to be shown on that plate were different from the actual facts?

A. No, sir.

Mr. Williams: Now, Mr. Wilkerson, I would like to have marked for identification, or else have it understood, that

those pages from the report of the Chief Engineer for the year 1902 may be offered in evidence later on.

Mr. Wilkerson: You can give the numbers of the pages to the reporter, and the numbers of the plates that have been previously identified by the witness, and those pages to which you have referred may be used for the purpose of impeachment or parol testimony, so far as he has identified them.

Mr. Williams: Q. Mr. Sabin, at how many points in the measured cross-section of the St. Clair River did you use the current meter in making your observations?

A. The section was divided into, I think, 21 partial areas.

Q. At what width of the river was it divided into that many areas?

A. The section is a little over 2100 feet in width, and then observations for discharge were taken 100 feet apart. The section was divided into 21 partial areas with a discharge station in the center of each, with the exception of the two end areas, the width of which varied with the water stage. Then within each of those partial areas the meters were placed at different points,—that is, not simply at one point in that 100 feet.

Q. You mean different points horizontally?

A. Both the vertical and transverse curves were observed for, but more particularly the vertical curve, that is, the change in velocity from the surface to the bottom.

Q. How many meters did you use?

A. I think 11 at one time was the most that we used, but ordinarily in taking the discharge, only two meters at a time.

Q. Well, now, in making the measurement at a given point, how did you arrange your meters? Were they suspended in the water one above the other?

A. They were, for getting what I have referred to as the vertical curve, that is, showing the changes in velocity from the surface to the bottom.

Q. And in such case how many meters would be used?

A. We used from 6 to 11 meters for that purpose.

Q. How many of these meters, or were they all, rated?

A. Yes, sir, they were all rated.

Q. How many of those meters that were used there were direction meters?

A. That information is given in the report; I can only get it from that.

Q. Is that in that same report that you have just referred to?

A. Yes.

Q. Will you give the page?

A. It is about 5369, for 1900; there is a description of the method of getting the vertical curves.

Q. How long a time was consumed in getting the vertical curve at any given point?

A. Station 1 was occupied three days in making observations, and there were six sets, that is, six settings of the meter for that, and 11 curves were observed, and in the stations further out usually more than that, but from three to four days' occupation; that was not continuous. I don't mean eight hours a day continuously, but they were occupied on that many different days, so that the vertical curve was obtained, that is, this relation of change of velocity was obtained under several different conditions.

Q. And what was the total length of time required to make a single measurement of the discharge of the whole river?

A. I think we took from two to four discharge measurements, running across the river two to four times in one working day. That is my recollection of it. That shows in the table which I have identified, the number of discharges that were measured on any given day.

Q. Ten hours or eight or sixteen?

A. Well, about ten, probably.

Q. Will you give us your opinion as to the degree of accuracy that is secured by the use of these meters, the percentage?

A. In order to make my answer to that intelligible I think I should know a little more definitely just what you have in mind, whether you mean under the conditions existing on one day, how close did we know the discharge when we measured it on that day,—is that what you have in mind?

Q. Yes.

A. I should say somewhere in the neighborhood of 5 per cent.

Q. You mean by that that the actual amount of water flowing might be either 5 per cent. less or 5 per cent. more than there shown?

A. For that one observation.

Q. For that one observation?

A. Yes, sir.

Q. Within a range, then, of practically 10 per cent.?

A. Yes, that is a rough approximation of my idea of the accuracy of it.

Q. What method did you use to determine the exact point on the line which was the water surface or the vertical plane of the cross section?

A. Horizontally?

Q. Where you had an upper line of a vertical plane?

A. The intersection of the cross section with the water surface of the river?

Q. Yes.

A. And how we located ourselves across the river, transverse to the river, along the line?

Q. Along the upper line, yes.

A. By the use of ranges on shore.

Q. How nearly accurate would you say that those determinations of positions were?

A. Within probably five feet.

Q. What precautions did you take, or what means did you employ to make sure that none of your determinations were vitiated by the shifting currents, and the changes of lake elevation due to the wind and eddies?

A. We measured the velocity of the current as it actually existed at the time we were there. There was no way of stopping the wind or the eddies.

Q. But those measurements you were making were later to be used in connection with the level of the lake in order to ascertain the relation one to the other?

A. Yes, sir.

Q. Now, then, did you have any means of making sure that that relation could not be ascertained because of temporary fluctuations in the lake level during the time of your observations?

A. The lake level was taken continuously during the time of the observations. We knew the lake level at each observation.

Q. But if the lake level rose suddenly by reason of some temporary cause, such as a wind, and remained in that position for a few hours, did you take that as an ordinary stage of the lake, as unaffected by that temporary condition, in ascertaining the relation between the two, the discharge and the level?

A. That observation was used with all of the information which we had about it, in the reduction of the entire series of observations.

Q. I don't know whether we understood each other when

I asked you the possible error in locating the upper line of your gauging section?

A. Those were located from the shore.

Q. The vertical location of the water surface at your gauging station, I mean?

A. That was considered to be the same as the elevation at the end of the section. That is what you are getting at is it not?

Q. At both ends or one end?

A. A part of the time it was read at both ends; usually at one end.

Q. Did you ever observe any difference in the elevation at the two ends?

A. Oh, yes, slight variations; nothing that was at all surprising?

Q. How great a variation did you observe?

A. I don't recall.

Q. Would it have been more accurate if you had located your line from both ends rather than from one end?

A. It would have been a refinement that was hardly warranted.

Q. Can you give us any estimate of the difference in elevation which you did observe between the two ends?

A. No, I have no recollection of that.

Q. Could you within any reasonable limits? Could you say an inch, or half an inch, or a foot?

A. I should think at times it might have been as much as an inch.

Q. Suppose that the level of Lake Huron was lower, would the increment become greater or less per foot of drop as the level of the lake was lower?

A. It would be very slight, if any change; the tendency would be to decrease the increment.

Q. Suppose the level of Lake Huron should drop, say, five feet, would there be a substantial decrease in the increment?

A. I should not expect a very serious change from a five-foot drop.

Q. Suppose it should drop ten feet?

A. I don't care to go into that.

Q. Would you have any opinion on it at all?

A. No, sir.

Q. You say you have no opinion as to whether the increment would decrease substantially?

A. No, there has never been known to have been as low as a ten foot fall.

Q. Suppose that Lake St. Clair is at the same elevation during a series of observations, and different elevations in Lake Huron, would you say then that the difference of the discharge in St. Clair River was due to the changes in Lake Huron alone?

A. If that was the only factor named, I would expect that the effect would be due to that change.

Q. What other factor would you expect to enter into that situation?

A. What part of Lake Huron are you considering?

Q. At the north of the St. Clair River?

A. At the head of the St. Clair River?

Q. The part that you observed during the time you made your observations, and upon which these plates are based?

A. A given level at a given point on the St. Clair River would not necessarily mean that the level at another point was always the same at the time that the level at the first point became the same. It would depend upon what made the changes in level at the time. That is, I can conceive of temporary effects, such as wind, which would pile the water up at one part of the river, and make a different form of water surface than when the same level existed at one of those points under natural conditions without wind.

Q. Assuming just natural conditions, without wind?

A. Then I should expect that the change in discharge, the observed change in discharge, was due to the change in Lake Huron, that being the only factor there.

Q. Did I understand you to say, in answer to a question asked you by Mr. Wilkerson, that a decreased flow through the St. Clair River indicated a lowering of Lake Huron?

A. Other things being equal, yes.

Q. There might be a decreased flow, owing to an increase in the elevation of Lake Erie?

A. Yes, sir.

Q. And that would not indicate that Lake Huron was any lower?

A. Not necessarily.

Q. You testified in reference to the ice effects. What is the relative importance of the ice effect in the outlet of Lake Huron, as compared with the ice effect in the outlet to Lake Erie, the Niagara River?

A. I don't know what the relative importance is, for a

term of years. I think that the effect on Lake Michigan and Huron,—or the effect on the discharge of the St. Clair River, —might be greater at times—I will change that just a little—

Q. What we are trying to get at is, would the ice effect tend to raise the elevation of Lake Huron more than the ice effect would tend to raise the elevation of Lake Erie, or less?

A. For the same retardation of flow in the outlet, the effect on Lake Erie would be greater.

Q. I mean the conditions as they exist, and as they are customarily to be observed?

A. I am inclined to think that the effects on Lake Michigan and Huron are greater than they are on Lake Erie.

Q. Would a change in the channel of the Detroit River affect the level of Lake St. Clair?

A. Yes.

Q. An increased cross-section there, having greater flow, would tend to lower the level of Lake St. Clair?

A. Yes, sir.

Q. State whether or not, in your opinion, the levels of Lakes Huron and Michigan are controlled by the hydraulic conditions at any single section in the outlet of those lakes?

A. No, I think not.

Q. In your opinion would changes in the channel of the St. Clair River at points other than at the Rapids affect the discharges of Lakes Huron and Michigan, for a given stage?

A. Slightly.

Q. Would a change in the level of Lake St. Clair affect the discharge from Lake Huron?

A. Yes.

Q. Did you make any computations from the result of your observations as to the discharge through the St. Clair River, and the elevation of Lake Huron, with a view to determining the increment?

A. That was one of the main purposes of those discharge observations.

Q. Well, you made the computation?

A. Yes, sir.

Q. And the result of your computation was that the increment of Lake Huron, based upon those observations, was 19,238 cubic feet per second?

A. Approximately that.

Q. What percentage of accuracy, in your opinion, does that figure represent?

A. I think that that may vary, as I said in my direct testimony, from about 16,000 to 23,000 or 24,000,—24,000.

Q. There is a range there of about 50 per cent.?

A. Yes, sir.

Q. And have you any explanation to offer, other than the lack of precise and accurate methods of determination of the difference in results obtained by you as the result of your observations and the results shown by these plats, as to the increment from Lake Huron?

A. It is not a question of accuracy of methods of observation; there is no such error as that in the observations.

Q. Did you use a different method of computation from those employed in this chart?

A. The difference is due to the amount of the change in discharge which is charged to the level of Lake Erie, and the amount of the change in discharge charged to the level of Lake Huron and Michigan. That is where that large possible error of increment comes in.

Q. Do you think it possible that there might have been a change in the regimen of the St. Clair River, and that that might account for some of the difference?

A. It is possible but not probable.

Re-direct Examination by Mr. Wilkerson.

Q. Counsel in cross-examination asked you something about changing bench marks. I think you testified on that.

A. In connection with those tables?

Q. Yes.

A. Yes, sir.

Q. Did that change have any relation to or bearing upon the determination of the increment or the lowering—

Mr. Williams: We do not claim it does have.

Mr. Wilkerson: You do not claim it does have?

Mr. Williams: No.

Mr. Wilkerson: Q. Now, counsel put to you some questions that were predicated upon the assumption that in measuring the levels of the lake at a given time, the measurement would be taken under conditions where by reason of a storm or some other local condition, the level of the lake would be temporarily affected by that. Assuming that you did at any one time take some measurements when there was that temporary condition, I wish you would explain a little more fully just how that particular observation would be treated so far as

correcting it with reference to other observations, and taken in combination with others, taking into consideration the fluctuation that the lake made?

A. That is the reason or at least one of the main reasons why these points which we get in making observations do not fall on the straight line, showing the relation between the height of the lake and the amount of discharge.

Q. Now, looking at one of those lines that are drawn there, treating it as a question of eyesight, as well as of mathematics, what is the fact with reference to any error that might be injected, by reason of temporary conditions at one time being counterbalanced or overcome by temporary conditions the other way at another time? How does that work out in practice, when you come to group all these observations together?

A. In a line drawn as this one is on Exhibit No. 1, there are about as many points on one side of the line as there are on the other. That is what we mean by saying that the line fairly represents the observations and the variation of any given point from the line shows the error there may be in that observation. If every measurement were exactly correct, we would only need to take two to get this increment.

Q. So that even though there may be a large chance for error in one observation by reason of temporary conditions when we have simply the single observation in mind, what is the fact with reference to the comparative error when we speak of the general result which is reached from the combination of a large number of these observations, and of many series of them?

A. A great many of the errors of observation are what we call compensating; that is they may at one time make the result too large and at another time too small. There are certain other errors which are constant errors. The compensating errors tend to compensate each other; and the effects of wind and storms and things of that kind are of that nature. And if they are so serious as to warrant it, they sometimes cause the rejection of an observation; although that is rather seldom done.

Q. Isn't this principle that you have just pointed out here something that enters into—is it or is it not something that enters into the determination of any rule which is derived from a long series of observations? Take for instance tables of mortality, derived from actual observation.

Mr. Williams: I do not assume that the witness is an expert on mortality tables, too.

Mr. Wilkerson: Q. You know in a general way how those tables are derived, do you not?

A. I think that that might be put as an illustration of any engineering data that rests upon observation; no observation is absolute.

Q. Now, I have used here, for the purpose of comparison, mortality tables, which are things that are used as the basis of computation in all the affairs of life and are recognized in courts as stating the results with substantial accuracy. For one time, for instance, there will be temporary conditions that intervene, as for instance the prevalence of an epidemic at the particular place where the observation is made; while there may be another period, at another place when there is something that tends to compensate that. That is, is that a fair analogy to—

A. I should hardly think so. If our engineering data were not any better than that—

Q. I mean not with respect to the degree of accuracy, but with respect to the method?

A. Qualitatively, yes, but not quantitatively.

Q. Mr. Sabin, if the water surface on the cross section may not be quite level across and the two gauges show slightly different heights, does the same condition obtain when the soundings are made, so as to eliminate any error which may come in by the arching of the river?

A. What I understood the counsel to have in mind when he inquired about that was a temporary effect due to wind, which may pile the water up on one side of the section slightly; and if that is what you are referring to, of course the soundings might not have been made under that same condition. But if the wind piled the water up on one side of a section by an inch at one time, it would be as likely to pile it up on the other side at another time, and it would be one of our—go in as one of our errors of observation.

Q. In the case in which you assume, in response to the question of the counsel on cross-examination, that the one gauge was an inch higher than the other, what would be the error that would come from that, would it be a substantial one; error in the discharge?

A. Very small.

Q. Can you state that more definitely than that, what do you mean by very small?

A. Perhaps one-tenth of one per cent.

Q. In speaking of this increment of 19,000 cubic feet per second, that is the one deduced from your observations, what do you say, Mr. Sabin, as to the range of those observations, compared with the range of the observations on the charts which have been used in this case?

A. I have not in mind just how much the range was increased by the later observations, but it was increased, appreciably increased; so that taking the new observations with mine, a larger range of height was covered, and therefore the deductions from it would be, on that account, better.

Q. Then there was some difference you said that grew out of the manner in which Lake Erie was treated?

A. Yes.

Q. That is the allowance that has been made on account of that in these later computations would make the increment larger than the one as you had it?

A. It did make it larger.

Q. And I think you have already said that so far as the size of the increment as a maximum is concerned, the figures that appear on these charts are at the limit on that?

A. Yes, I think that that would be—for St. Clair I think that is the largest determination that I would expect to be the truth.

Q. In other words in dealing with those, whose interest it is to have the increment as large as possible, would you say that the substantial considerations have all been resolved in favor of the large increment?

A. I gave that as the upper limit of my determination.

Re-cross Examination by Mr. Williams.

Q. Mr. Wheeler in his testimony yesterday—you heard him testify?

A. I heard most of Mr. Wheelers' testimony.

Q. He testified that he had compared the observations that were platted here with the published observations, did he not?

A. I don't recall whether he said that he had compared the observations on these plates with the published observations or not.

Q. Assume that he did say that, what observations have been published other than those to which your attention has been called this afternoon?

A. The observations of 1902, in the report of 1902.
Q. His attention was called to that?
A. Yes, sir.

Further Re-direct Examination by Mr. Wilkerson.

Q. I do not recall, Mr. Sabin, whether you covered this ground or not, but to make sure I want to ask you a question with reference to the degree of the precision of these gauge readings in hundredths of a foot. What is your idea about that?

A. The gauge readings which were published in the 1903 report, and have been mentioned in this case, are monthly mean levels. Those are obtained by taking one or more observations per day on a given gauge. It is possible to have in one reading a considerable error; probably they are easily read within one-tenth of a foot; but occasionally mistakes may be made larger than this. I would expect that the result given for any month as the monthly mean would not have an error in it due to such errors of observation of the gauge of more than three-quarters of an inch.

Q. Have you anything to add in the way of a reason for that?

A. Principally from my experience in looking over gauge readings and reducing them, that it is so seldom that a mistake is made that I should think the final result, being a mean of a large number of observations, would be quite accurate.

Q. Then there is the check of the two gauges, is there not, on the same lake?

A. In many places there are two gauges.

Further Re-cross Examination by Mr. Williams.

Q. The testimony you have just given in response to counsel's questions, applies, does it, to the elevations recorded on pages 2867, 2868, 2869, 2870 and 2871 of Appendix FFF of the Annual Report of the Chief of Engineers of 1903?

A. It applies so far as that class of errors is concerned.

Q. And you would consider that the elevations recorded on those pages to which your attention was called correctly represent those elevations, subject to only the very slight errors which you have indicated might have crept in?

A. No, sir, I do not; I do not agree with that; I said so far as the errors of the kind which I mentioned were concerned.

Q. What other errors do you take into consideration in the compiling of these tables showing the elevations of these lakes?

A. Those tables give the difference in elevation between the lake surface and sea level.

Q. In addition to the error that you have pointed out as possible in the gauge readings, what would be the probable error or possible error relating to the elevation between sea level and zero on the gauge? You mean that there may be an error in addition to the error of the reading of the measurement between the sea level and the zero?

A. Yes, that is one error.

Q. To what extent would you say that error prevailed if at all, within what limits?

A. I don't know anything about the size of that, possible size of that error, but I will say this, which will answer your question, I think: that the difference between the error for one lake and the error for another lake is not very great.

Q. When you say not very great what do you mean?

A. Well, not greater than three-tenths.

Q. Of a foot?

A. Yes.

Q. And that is a constant, a continuous error?

A. For that given lake, yes, as published in those tables, yes. Then there is one other kind of error, or one or two other kinds of errors that may be in that table.

Q. Just enumerate them if you will; we want to get them?

A. The leveling from the bench mark to the water gauge may be an error depending upon the length, the distance; that will usually be less than one-half of a tenth.

Q. Are there any others?

A. No, I don't recall any others, so far as giving the elevation at the place where the gauge is located is concerned.

Further Re-direct Examination by Mr. Wilkerson.

Q. Just one question: with reference to this possible error in the elevation of zero on the gauge above the sea level, is that an error which would in any way affect substantially the result attained for increment of flow?

A. No, it would have practically no effect on that quantity.

Adjourned sine die.

Detroit, Michigan, May 24, 1909.

Ten o'clock a. m.

WILLIAM LIVINGSTON, a witness called on behalf of the government, was first duly sworn and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. State your name please.
A. William Livingston.
Q. Where do you live?
A. Detroit.
Q. What is your present business or occupation?
A. I am at present with the Lake Carriers Association.
Q. What is the nature of your work in connection with that position?
A. I am supposed in a general way to look after the interests of the association. We have an executive committee that I work in conjunction with. I am supposed to look after, to a certain extent, everything that pertains to or affects the interests of navigation, in the way of improvements, etc., for instance deepening of harbors and rivers.
Q. How long have you had to do with matters relating to the navigation of the lakes?
A. Thirty-five years, certain.
Q. In a general way, what experience have you had in connection with such matters?
A. Well, as owner of vessels, handling of them, managing of them.
Q. Have you had any practical experience?
A. Well, a little.
Q. In connection with the management of vessels?
A. What do you mean by practical experience?
Q. Owning and handling them.
A. Some.
Q. I mean for you to cover in outline just what your experience has been, in matters relating to navigation on the lakes?
A. Well, my first vessel experience, so far as my memory goes now, dates back to 1867; I used to handle a good deal a small boat at that time; and I have been continuously connected with the lake transportation business. I think, on re-

flection, that makes 40 years instead of 35, and I have been continuously in the business all that time.

Q. What is it that determines the size of vessels which may be used in commerce on the lakes?

A. You mean at the present time?

Q. Yes. For instance, what determines how large a boat may be used in carrying on commerce between Buffalo and points up in Lake Superior?

A. There was a boat launched the other day that is 607 feet over all. I didn't measure it, but that is the statement made to me. That is the Chenango. I think the boat on that measurement would be a lot the largest boat on the lakes. She was launched either three or four weeks ago Saturday.

Q. What determines the depth to which boats engaged in lake commerce can be loaded?

A. The lowest point going through the rivers and, of course, the harbor or port she is consigned to. For instance, if a boat were loaded in Chicago or South Chicago, she would have to load to the depth of water there at the present time. She would be confined to two things: First, in rivers to the depth of water on Ballard's Reef, down here in the lower Detroit River, the reason for that being that the water crossing Ballard's Reef is a little shoaler than the Lime Kiln Crossing and at Bar Point. I should add, of course, if the harbor wherever she was consigned to and went to load, if that harbor was shoaler than Ballard's Reef, she would have to take that into consideration. But I do not know of any just now where she would have to take that into consideration. I think Ballard's Reef would be about the governing point.

Q. What about boats that are carrying to points on Lake Superior, Duluth, for example?

A. We take the depth of water there from the Poe lock. In other words, the engineer at the Poe lock, the assistant engineer, Mr. Sabin, keeps a constant gauge of the water there; and whatever depth he gives that we can load safely to going through the lock is what we use. It started in this season at 18.3; it is now 18.8. You can go through the Canadian lock with a little more water; I don't know just how much, because we do not have an official report on that, the same as we do on the Poe Lock; so that the Poe lock has to govern on that. Going there, it makes no difference if you load to a hundred feet outside, you have to take the shoalest spot and be governed by that. The water is lower this year in the Lake Superior district.

Q. Having in mind your experience with reference to matters connected with the navigation of the lakes, and speaking from that experience and from your knowledge, I wish you would state what would be the effect upon the load that a boat can carry of the lowering of the water at any one of these critical points in the channels of the lakes? For example, suppose that in some way the water in one of those channels was lowered an inch or two inches. What is the relation between that and the size of a load that a boat could carry going through the channel?

A. Speaking of the average?

Q. Well, take any boat that you have in mind. I would like to have you give us an explanation of that relation; state what the effect would be, based upon your experience.

A. Well, approximately speaking, taking the smaller class of boats, they are rapidly becoming obsolete.

Q. Go ahead and make you explanation in your own way.

A. As fast as they get into trouble or become disabled or anything of that kind, or lost, they are not replaced. Of course, now everything is steel. You take the last ten years, the last eight years particularly, has worked a sort of revolution here on the lakes. For instance, seven years ago—I am approximating; I can't give you to the month perhaps, but about seven years ago, for instance, the steamer A. B. Wolvin was built; and when she was built she was the largest vessel on the lakes. She exceeded in tonnage by 3,500 tons the next largest vessel. All the boats that have been built from that time on, with the exception of boats that were built for some specific traffic, say for instance the package freight traffic, something of that kind, have all been built of her type, all through; some a little smaller. But the smallest boat that is built now for business purposes, I know of none that will run under say 7,500 to 8,000 tons; and they run from that up. We have boats now that will carry 12,000 gross tons. I figure that the average per inch when a boat is loaded, say 18 feet or more, would be from 80 to 100 tons per inch. You take the lowest average, 80 tons, or cut it a little more if you choose to 75 tons, on the present rate of freight.

Q. Let me put a question to you there, Mr. Livingston: Having in mind this average boat with reference to which you have been testifying, and assuming that there was a permanent lowering of the water at one of these critical points of navigation of one inch, and basing your answer upon

freight rates as they exist now, what would be the loss to that boat?

A. Of one inch?

Q. Of one inch on the navigation of a season, we will say.

A. Assuming the average boat, and putting it on the basis of 80 tons—you could cut that to 75, but call it 80 tons just for illustration purposes, assuming as a fair average, in other words a very conservative average, the boat made twenty trips during a season, one inch would make a loss to each boat of over a thousand dollars in a season. Each inch would add just so much more to it. In other words, a boat going down and crossing Ballard's Reef drawing 18 feet or 19 feet, each inch you cut from that would be just that difference in the course of a season. The loss would vary as the freight rates vary.

Q. Now, you have knowledge on the subject of the number of boats that are engaged in commerce on the lakes in a general way, have you, Mr. Livingston?

A. Yes, sir.

Q. Have you given any consideration to the question of the total loss to commerce on the lakes, which would result from this lowering we will say, of one inch, basing that upon the number of boats that are engaged in lake commerce. Have you given any consideration to that subject?

A. Well, I could do this: We have, roughly speaking, in our association—of course you understand I confine my attention practically to our own association—we have about 600 boats.

Q. I wish you would give us anything that would be helpful in determining the loss to the commerce of the lakes occasioned by that lowering, based upon your experience and your knowledge; any facts that you think bear on that within your knowledge, I wish you would give it to us.

A. I would be glad to hand you in a computation; I would have to make it. It would not take me long to make it. I can also in that connection give you, as we are just getting one out now, a printed list of all the boats in the association, and the tonnage, both gross and net, the tonnage of each.

Q. You started out by giving us the effect of that lowering upon the carrying capacity of one boat?

A. Yes, sir.

Q. You have knowledge, of course, with reference to the total number of boats that are engaged in commerce on the

lakes. I want you in a general way to give us the facts with reference to the aggregate effect of this lowering upon commerce, so far as you have knowledge on the subject.

A. Well, do you mean all the vessels engaged in commerce on the lakes?

Q. Excluding, of course, those that are engaged exclusively in traffic on Lake Superior.

A. Yes, but what I am trying to get at, Mr. Wilkerson, is this: I have got a fairly thorough knowledge, I think, of everything pertaining to the boats that belong to the Lake Carriers Association. I am not quite so familiar, of course, naturally, with the boats outside of it. I could give you pretty accurate statements regarding, say, the six hundred boats that belong to the association. That would take the cream of the carrying capacity on the lakes.

Q. Answer the question on that basis.

A. It would give you a great big average. I want you to understand when I speak about registered tonnage, for instance, when you have a boat that will carry say in the neighborhood of 6,000 tons, a 600 footer, in the neighborhood of say 6,000 tons gross tonnage, custom house measurement, that boat will carry 12,000 tons of freight.

Q. Have you given the number of vessels that belong to the owners who are members of your association, approximately?

A. I will give it to you approximately.

Q. About 600 I think you said?

A. Yes.

Q. What percentage of that number of vessels is engaged in through traffic?

A. By through traffic you mean that pass the Detroit River, loading above?

Q. Yes. Practically all of them?

A. All of them, yes.

Q. Would all of the 600 be affected by the lowering of the lake levels to the extent of an inch?

A. No, sir.

Q. Which would not?

A. You take the boat for instance, as you can readily see, the boat that was so small that it didn't draw depth of water enough to be affected by the water, for instance, at the lowest point, of course an inch would not affect that boat.

Q. About what proportion would be affected by lowering?

A. I would prefer before stating it under oath to figure it out, but if I were to give it to you approximately, I would say 70 per cent.

Q. Seventy per cent. would be affected?

A. Yes.

Q. Would you say at least 70 per cent.?

A. I think so. I can figure it out. I can give you one fleet, if you care to have it, approximately.

Q. All right.

A. We have one fleet on the lakes that has 73 ships.

Q. What fleet is that?

A. Pittsburg Steamship Company.

Q. Give us the facts with reference to the Pittsburg Steamship Company.

A. Seventy-three ships have been loaded to 19 feet, but 18 of those 73 could load to 21. These boats in a normal season carry 10,000,000 tons, so that if you take these boats, they will make more trips than I gave you, more than 20, perhaps, in a season, but I did not think it was fair to take them, for the reason that they are peculiarly situated. In other words, they can make more trips per season than any other fleet on the lakes, owing to the advantages which they have in their loading and unloading facilities. No other fleet on the lakes has the advantages they have for loading and unloading, facilities for dispatch. But if you take that fleet alone for instance, if you cut them down to 20 trips, was that two inches you figured on?

Q. Figure it on the basis of an inch.

A. The loss for that fleet alone would be, roughly speaking, over $85,000 on one inch; that is on the present freights.

Q. I think you said that of the vessels that were connected with your association about 70 per cent. would be affected by this lowering?

A. Yes, sir. I don't give that as positive.

Q. Taking it on the basis of 70 per cent., what would be the total loss to the commerce of the vessels that are connected with your association? I wish to get a general idea on that.

A. Roughly speaking, about $650,000.

Q. That is for one inch?

A. That is for one inch.

Q. What proportion of the vessels that are engaged in commerce on the lakes and that would be affected by this low-

ering, would you say are connected with your association? I put that with a view of getting some idea of the total effect. You know approximately, do you not, about what percentage of vessels that are engaged in commerce on the lakes, that is of the largest, the ones that would be affected, belong to your association?

A. The lumber fleet would be out entirely, because none of the lumber fleet draw enough water to be affected. But outside of that, if you take the boats in the ore and the grain trade and that class of boats, I should think seven-eighths of them would be a fair estimate.

Q. That is seven-eighths are in your association?

A. Yes, sir.

Q. You think you are within safe limits when you say more than 80 per cent.?

A. I think so, sir.

Q. More than 80 per cent. belong to the Association?

A. I really do not know of any—yes, I think that is a fair estimate.

Q. So that the total loss to the commerce of the lakes would be about one-eighth more?

A. Yes. I am speaking now of the depth of water. I mean to be understood this way: that seven-eighths of the loss would be borne by the members of our association, from the fact that more than seven-eighths of the boats that draw that draft of water are in the Lake Carriers Association.

Q. When you have given us this information with reference to the loss to the commerce on the lakes from that permanent lowering, in order to get the total loss, you would have to increase the figures you have given by the amount lost by the vessels outside of your association?

A. Yes; the figures I have given, $650,000, are what 70 per cent.—I am not sure but I have made a mistake, because I was figuring the whole, and I have made a mistake on that. I was figuring the whole, and there is a certain percentage that would not load to that depth. I took the whole 600 vessels and I made a mistake. There is a portion of our fleet would not be affected, because when they are loaded to their utmost capacity, on account of their size, they would not be affected.

Q. The correct answer would be 70 per cent. of this $650,000?

A. Yes.

Q. Which would be between four and five hundred thousand dollars?

A. Yes, I have added 30 per cent. that I should not add. I think that is a very low estimate, but I had to give it approximately.

Q. That would be between four and five hundred thousand dollars?

A. Yes, it would go half a million, easy.

Q. You think that is a low estimate?

A. I think that is a low estimate, yes, sir.

Q. Now, coming back for a moment, Mr. Livingston, to the question of limitation upon the size of the vessels which engage in commerce on the lakes; what would be the effect with reference to the size of those vessels, if it were not for the limitations that are imposed by the depth of water in these critical points of navigation?

A. Why, it would very largely increase their carrying capacity, of course. You know the question of the 25-foot channel has been brought up a number of times. In fact, a survey has been made in some places regarding it, but the cost was so very great—

Mr. Williams: Just a moment. I object to the answer to this question as not being responsive to the question.

The witness: Well, sir, if you put the question so I understand it, I will be glad to answer it.

Q. (The question was read to the witness.) The fact I am trying to bring out, Mr. Livingston, a little more definitely is this: it relates to the extent of the effect of this lowering of the lake levels upon the future commerce of the lakes, and that in relation to the size of the vessels which can engage in that commerce.

A. Naturally the size of the vessels has to be limited to its present capacity, or, that is not putting it fairly, because we are building vessels right along with reference to getting a greater depth of water; consequently, all the vessels that are built now are built with reference to that in the future. That is, that we will eventually get the 25-foot channel. I can put that another way: all our modern vessels could load considerably deeper if the water would admit of it; in other words, if the shallow spots would admit of it.

Q. That is the fact I wanted to bring out.

A. Just wait one moment; I think I have something in my hand here; I did not know just what you wanted. (Referring to memorandum.) There is one fleet of some 18

boats that can load to 21 or 21½ feet; quite a number of fleets, I have not got them all here. There are none of the modern boats but what could load to a greater depth than that, load now, provided they had the water to do it.

Q. Is there any relation, Mr. Livingston, between the draft of a boat and the length of a boat?

A. They are all built in proportion.

Q. I will put a leading question to you: is the length of the boat in any way limited to the draft of the boat, as a matter of practical construction?

A. Well, it is supposed to be, but you see here on the lakes we have been compelled—we could not get any deeper under the present condition of affairs, and so the result was they have gone to length. They are limited, of course, in breadth. No, I will qualify that, because the Poe lock has 100 foot gates. The Canadian lock, the Canadian Sault, that lock is 60 foot wide, so, of course, going through that lock they are limited to the width.

Q. The question is, when you impose a limitation upon the draft of a boat, do you or do you not as a result of that impose a limitation upon the length of a boat that may be constructed with that particular draft?

A. It is generally figured that every marine architect in figuring out the cost of the boat, that he makes her depth—just as they do with the vessels on the ocean—he makes her breadth and her depth of beam proportionate to her length. We will say 1 to 10 the scale may be; that varies. But here on the lakes, on account of the shallowness of the water, we have been compelled to go outside of this variation, as evidenced by the fact that we have got quite a lot of 600 footers on the lakes and if they had been built strictly according to the scale they would have had greater depth on account of their length. But the theory was they would put in compensation straight against that.

Q. These boats that are constructed that way out of proportion you say—

A. I do not say they are out of proportion.

Q. Out of the orthodox rule?

A. Out of the standard rule.

Q. Out of the standard rule, do they hog in the middle?

A. No; the way that they have—as a matter of fact, most of these large boats have been made up in this way, so as to comply with the standard rule; they have given them a greater depth of water in anticipation of getting three or four more

feet of water within a reasonable time, so that although they do not actually draw it, they have still got the depth of hold. It would be pretty difficult, a man would be a bold man to say just what limits we will reach here on the lakes, any more than they would on the ocean.

Cross-Examination by Mr. Williams.

Q. What is the depth of water at Ballard's Reef?

A. It is 20 feet today. I think the water has been coming up a little.

Q. What is the depth of water at the Poe lock?

A. The depth of water at the Poe lock is 18 feet 8 inches, the latest report I have.

Q. The real critical point, then, is the Poe lock, is it not?

A. Coming from Lake Superior.

Q. Outside of Ballard's Reef that is the real critical point?

A. Yes; the Lime Kiln Crossing has always been the "Hell Gate," you know.

Q. At the present time what is the depth of water at the Lime Kiln Crossing as compared with Ballard's Reef?

A. Well, it is the same thing, 20 feet. Ballard's Reef is the gauge for Lime Kiln Crossing; it is just at the entrance, you know, of Lime Kiln Crossing.

Q. In your experience, is it your observation that those who are building vessels for lake traffic are building with a draft to meet the present or the future probable depths at these critical points?

A. I think the majority of the boats that are built now are built with a view to future depths. There is a strong, definite feeling in the minds of many of our vessel men and owners that we will get 25 feet. The question of cost is what comes up, getting the appropriation from Congress.

Q. Suppose there were an unlimited depth of water, that is, I mean a depth sufficient so that it could not in any way interfere with the draft of vessels on the great lakes, and at these critical points, to what depth would you consider it practicable to construct a lake vessel, what depth of draft, assuming there was no limitation whatever, so far as the critical points are concerned?

A. You mean that to apply to harbors, too?

Q. Yes.

A. Because it would not make any difference if you had a hundred feet outside, if you only had 20 foot depth in harbors.

Q. Assuming harbors having sufficient depth to meet any requirement that you might have?

A. I could not place a limit on that. Perhaps I can answer you in another way. You remember when the Great Eastern was built on the ocean, she was 640 feet, and was considered a failure. The result is now we have big boats in commission on the ocean that are 800 feet in length, 789, the Lusitania and Mauretania. There are two boats under construction so I am told—I do not vouch for it, but I think the contract has been let, although I am not positive about that, to build two trans-Atlantic liners of 1,000 feet.

Q. What is that thousand feet?

A. Thousand feet over all.

Q. That is in length?

A. That is in length.

Q. But I am speaking of the depth of draft?

A. Well, they will have boats, the deepest channel they can come in, the Ambrose channel at New York, when that is completed is to be 40 feet in depth.

Q. What I was trying to get at was this: Assume you are not limited in the depth of water either at the critical points on the Great Lakes or in the harbors, and that you are to do business, what amount of draft would you consider it practical to have in lake carrying boats?

A. Oh, I could not limit that. If you have your unlimited water, could draw any amount of water you wanted, I could not limit that. I could not give you—would not want to pass an opinion on that, because you see here ten years ago if a man had—

Q. Never mind about ten years ago. Answer the question.

A. I beg your pardon, I want you to mind about that, because ten years ago—you are asking me questions and I want to be straight about it—ten years ago if I or any other man in the business had stood up and predicted boats of the size of the Wolvin and the present line of boats we are building would ever be built on these lakes, that man would have been considered a fit candidate for a medical asylum.

Q. Is that the reason you say you do not want to make any prediction now?

A. Yes, because commerce on the lakes has gone forward with leaps and bounds, and I would not attempt to predict what the future might be.

Q. Now, assuming that there was 25 feet of water at the critical points and in the harbors in which your proposed

lake carrying vessels are to do business, what would be according to your information and experience the normal length over all of a boat drawing say 22 feet?

A. It would depend a little on her beam. You take such boats, for instance, as the Chenango launched the other day—

Q. I am not asking you for illustrations. If you can answer the question I wish you would; if you can't answer I would be very glad to have you say you do not care to express an opinion?

A. Then I will say no, I cannot.

Q. Is it true, according to your information and experience that vessels are now constructed longer than they would be constructed if it were not for these shallow points, for the purpose of carrying the same load?

A. Yes.

Q. And that increased length is for the purpose of compensating for the decreased draft, is it?

A. Yes, sir, but it is made up in beam, you understand, in breadth, to some extent.

Q. But the object of that is compensation for the decreased draft?

A. Yes, sir.

Q. The tendency, during the past ten years or so since 1900, has been to increase the size and draft of lake vessels, has it not?

A. Yes, sir.

Q. Can you state approximately the increase in average carrying capacity of lake vessels since 1900?

A. Approximately, yes.

Q. About what increase would you say?

A. Well, let me think a moment. Did you say since 1890?

Q. 1900?

A. Oh, 1900. Since 1890, about the largest boat on the lakes was 3,000 tons, and when I speak of tonnage—

Q. You say 1890, you mean 1900?

A. I will get to that in a moment. When I talk about the carrying capacity that has nothing to do with the Custom House measurement. In 1890, about the largest boat on the lakes carried about 3,100 tons of ore. It gradually increased from that up to 1900, until we may have had a boat that reached a carrying capacity of 5,000 tons; I am not positive about that. But there has been an increase from 1900 up to the present time of the difference say between a boat that could carry 5,000 tons up to the present carrying capacity.

We have had some boats that I think have gone into South Chicago that carried over 12,000 tons.

Q. Would you be safe in saying that the average carrying capacity of the lake vessels has increased a hundred per cent. since 1900?

A. I should say so, yes, sir, all the new vessels built.

Q. And that refers to the new vessels built?

A. Yes, sir.

Q. You have stated in answer to Mr. Wilkerson's questions, but I do not understand it and perhaps you can explain it so that even I can understand, that the gross tonnage would be 6,000 tons, but the boat would have a carrying capacity of perhaps twelve thousand?

A. Yes. I have some data I could give to you on that.

Q. Just explain how that is. I do not care anything about the details of it.

A. It is the government system of measurement. That is all I can tell you. It has been used ever since I have had any experience. For instance, take boats like the Gary and the Corey and this larger class of boats, 600 footers, their tonnage will run 5,900 tons, that is Custom House.

Q. That is gross tonnage?

A. Yes.

Q. That is according to government measurement?

A. Yes.

Q. What you would actually carry is what you will weigh and collect freight on?

A. Yes. It goes all the way through. For instance, I happen unfortunately to own a boat; she has a Custom House measurement of 1,700 tons. She carries for the present draft of water about 3,150 tons of ore.

Q. Mr. Livingstone, what would you say as to the comparison, if any, that you may be willing to make between the facilities for lake commerce at present and the demand for shipping facilities on lake carrying boats? Is there a sufficient number of boats to take care of the traffic?

A. To-day there is.

Q. And if there were a greater demand for transportation facilities on the lakes, there would be an increased number of boats to take care of that demand very probably?

A. We generally build a little ahead, always.

Q. What would you say as to the present situation, that you would be able to take care of more commerce than is actually taken care of on the Great Lakes, with the present facilities?

A. If the business of the country was normal, we would have but little if any tonnage to spare. Last year, being the panic year, or 1907 rather, you know how badly that affected the iron and ore trade, and what a large percentage of tonnage that is on the lakes, and the fact that Congress is chewing away just now on the tariff bill—

Q. Take last year, for instance, you had an excess tonnage?

A. Oh, we had excess tonnage, last year was the panic year, 1908.

Q. Did you have any excess tonnage in 1907?

A. No, not in 1907. Every available ton in 1907, so far as my knowledge goes, was in use; the largest year in the history of the shipping business on the lakes occurred in that fiscal year. I could give you the exact figures from my report in the office, but I haven't it with me. It was the largest in the history of the United States.

Q. What is the expense connected with the operation of one of these large lake freighters for a season, approximately?

A. Well, you know managements differ a little; approximately say $160 a day.

Q. That would be for how many days?

A. We generally figure about, being in commission, generally figure 240 days; that is for an average. Some seasons are a little longer; some are a trifle shorter.

Q. Two hundred and forty days at $160 a day?

A. $160, I am giving it to you approximately. You know some men will run their boats a little more economically than the others; some will carry more cargo, more passengers than others, and these things vary. Some will live better than others.

Q. In your opinion then about $40,000 would cover the expense?

A. Roughly speaking.

Q. The figures you have given would approximate $38,400?

A. The insurance on one of these boats amounts to between $16,000 and $17,000 dollars a year.

Q. Do the figures you give include insurance?

A. Yes, sir, I figured that. You understand that was an approximate figure because you see the insurance foots up so on a modern vessel. To-day, the insurance runs between $16,000 and $17,000.

Q. In giving your estimate, approximate estimate, do you

include anything in that for interest charges, or is this just operating expense?

A. Those are operating expenses. Include what did you say?

Q. Interest charges or depreciation on the vessel?

A. No, sir.

Q. What is the cost of one of those large vessels approximately?

A. Ten thousand tons, they run about $400,000. In some cases they will be built for a little less; sometimes a little more. It depends on the state of the iron and steel market, but about $400,000. If you take a 600-footer, built right up to date, and she is fitted up with perhaps a private cabin and separate dining room, private dining room, some of them run up perhaps to $440,000, or say $400,000. They will carry 10,000 tons of ore on an average draft of water; some even with a little less, you know.

Q. What in your judgment is the average life of one of those vessels?

A. These steel vessels?

Q. Yes.

A. I can't tell you that, because you understand that steel ships are comparatively new on the lakes as compared with the ocean. Then comes up the question as to how far rust is going to affect it, whether fresh water is going to affect that. That is a matter I would not like to pass on.

Q. What is the longest that any one boat has been in service?

A. I should say fifty years.

Q. How long has the longest one you have known been in service?

A. That is the steamer Michigan. She has an iron hull. She has been in service nearly sixty years now. They cut a piece of iron out of her hull, that must have been nearly twenty years ago, she was then forty years old, and the government had their engineers cut a piece out of her hull to look at the iron, etc., and they pronounced the fibre in connection with the piece they cut out as sound as the day it was built.

Q. If you were going to make an estimate, do you think fifty years would be conservative?

A. Yes, sir, I would. At that, I am only guessing. I think this: a good deal would depend on the care a man took of his vessel, having it scraped and the rust taken off; keeping it

painted inside and all that. It is like a man taking care of his health.

Q. What would you consider a fair interest charge, if you were going to figure on a valuation of $400,000 on a boat, and if you were going to ascertain whether you were making a profit or not?

A. You mean depreciation per year?

Q. No, I say interest charge?

A. Oh, interest on the investment; that is the return a man ought to have?

Q. Yes, if you were to figure whether or not you had a profitable year, you would figure first interest on your investment of $400,000?

A. I would.

Q. Your depreciation, and your operating expenses and your receipts. What interest charge would you consider a fair charge?

A. Well, I would figure something this way: I would take first, of course, all the actual expenses of the boat, all the money paid out and I would add to that 5 per cent. for depreciation. And then I would figure the return I should have on the face of that, above all.

Q. Would you consider it necessary to figure 5 per cent. depreciation on a boat that was likely to last fifty years?

A. Well, yes I would.

Q. Or would you include in that 5 per cent. the maintenance of the boat, repairs, and keeping it in condition?

A. Well, perhaps partially, but if you will let me explain when I say partially, you understand I would expect the hull of the boat to outlast for instance several series of boilers. Boilers subject to pressure, etc., wear out and have to be taken out. I would not class that in; so that I would take that out of depreciation. You take the life of an engine; take our triple expansion or quadruple, whatever they might be, they would have to be probably replaced after a certain length of time. I would in that 5 per cent. include the up-keep of the boat, keeping the boat in good condition, and any minor expense I would include in the 5 per cent. Then there is another thing you have to figure on, the changes in boats. You build a boat to-day, you think she is modern and up to date, you think you have everything up to date, but five years later something else may come along, and you will find you are behind the light house; and that 5 per cent. is little enough depreciation.

Q. Would you consider 5 per cent. also a fair interest on the investment?

A. No, sir, I would not.

Q. I am not speaking of profits on your season's work. I am figuring on the value of the money invested in the boat?

A. I think that ought to be 6 per cent. for this business.

Q. About 6 per cent.?

A. Yes, sir, I think so.

Q. Do you know of any bond issues being floated on boats of that character?

A. Well, yes.

Q. At what rate of interest?

A. Six per cent. But I will say this, so that you will clearly understand me, that the usual way of issuing these bonds is on a 5 per cent. basis, and they are issued for ten years and 10 per cent. are retired each year, but some bonds particularly —and that perhaps is not a fair criterion. Last year, you know, was the panic year, a good many bonds, a large number of bonds in fact—I speak from absolute personal knowledge on this—were sold below par sufficient to make them 6 per cent.; in fact went down to 6½.

Q. A 6 per cent. estimate on the investment would be liberal to cover even panic years, wouldn't it?

A. Why, you clearly understand that I do not think 6 per cent. investment for a man's profits in the business—

Q. No, I am not talking about profits.

A. Yes, I think 6 per cent.

Q. That is something you ought to get before you figure profits?

A. Yes, sir. Then I understand you this is 6 per cent.

Q. Is there anything else you would figure on in the way of charges against your investment in a boat of this character, besides what you have mentioned; 6 per cent. interest on the investment, 5 per cent. for depreciation and up-keep, $160 a day approximately for operating expenses?

A. Yes, and insurance.

Q. And insurance. Is there anything else that will be proper to be charged?

A. I don't think of anything else now. I might just add one thing: you understand your expense account is dependent on conditions; is liable to vary some for this reason: sometimes provisions advance and sometimes labor costs more.

Q. That is included in your estimate of $160?

A. No, I am talking about the present situation.

Q. The normal situation?

A. The present situation.

Q. And is it normal?

A. Yes, it is normal. You never can surely tell just what labor is going to do.

Q. It might be a little more or a little less?

A. Yes.

Q. It is as likely to be one as the other?

A. Our experience on the lakes is it has never been less; it has been a constant increase. The experience of the last twenty years shows it has been in increase; wages increased, materials increased, living has increased. Help demands a great deal more than it used to.

Q. Have you any data from which you could give us accurate information as to the amount of money expended in any one season for repairs and maintenance of one of these large boats?

A. I could get it for you; but that is outside of extraordinary expense. You understand if a boat had a collision or broke down or for instance if she broke her cylinder, something of that kind, that would be extra. You mean a boat that runs through with just the ordinary—

Q. The average expense?

A. Yes, I could give you that; I could get it for you. I can't give it to you right now.

Mr. Wilkerson: To get the average, you would have to take the extraordinary with the ordinary?

Mr. Williams: The average conditions.

The Witness: I understand you mean a boat that runs through the whole season with the ordinary risk she takes, with nothing unusual happening during the season.

Q. That is right.

A. Because these accidents vary so much.

Q. Those accidents are usually covered by insurance, aren't they?

A. Yes.

Q. So that that would not be a proper element of charge in this?

A. As a rule they are covered by insurance.

Q. You will bring us those figures I have just asked for, this afternoon?

A. Yes. I do not know whether I can give it this afternoon. I will agree to turn it in the next day or two.

Q. Just as soon as you conveniently can, and before we conclude the hearing?

A. I have got a few things to do just now. I may want to increase that expense account per day before I get through.

Q. Now you have given us an estimate of the value to the vessel owner of a carrying capacity of 80 tons?

A. Yes, sir.

Q. For a season. And you estimate that value to be about a thousand dollars?

A. Yes.

Q. Basing that on present freight rates?

A. Yes, sir, based on 65 cent rate, from the head of the lake. This reduction of rate was made from 75 cents to 65.

Q. Was that thousand dollars a season gross or net?

A. That thousand dollars is gross.

Q. Nothing taken out for the expense of loading and unloading?

A. Yes, sir. I made a low estimate, just jumping at that, but I made the basis, my hasty conclusions, I made it on the basis of 65 cents, and it costs 20 cents a ton to unload.

Q. Did you make that estimate on the basis of 65 cents?

A. That was a rough estimate. I am trying to explain it was based on the present rate on freight, 65 cents a ton from the head of the lake. Out of that freight rate is paid about 20 cents a ton for unloading.

Q. What I am trying to get at is, does the thousand dollars include anything else; is that gross, without taking into consideration any of the expenses?

A. That is gross. That would be the only expense that would attach to the boat, because there would be the same expense for fuel.

Q. That applies to your half million dollars that you mentioned as being the loss to the entire fleet?

A. What I mean to be understood is this: that the actual loss to the boat would be this, supposing the rate was 65 cents a ton, that the actual loss to the boat would be 45 cents a ton.

Q. Is there any other expense connected with the carrying of this extra 80 tons besides the cost of unloading it?

A. None that I know of. The crew would be the same, the actual coal you would burn would be the same. I do not know of any other expense I could figure.

Q. Would a large load take any more coal than a small load?

A. I think it would be almost imperceptible, that.

Q. Would it take any more coal, if the vessel was capable of being loaded two feet deeper?

A. Oh, yes, if that is what you are getting at; I did not misunderstand you a bit. You are talking about 80 tons. I do say this: you take the percentage of coal, take it your way, take the percentage of coal used for six inches; you take the percentage of coal used for a boat drawing 19½ feet, and a boat built exactly like it, of the same power and the same boilers; one drawing 19½ feet and the other drawing 20 feet, the boat that draws 20 feet would burn some more coal; there isn't any question about that at all, but the proportion would be small. I think it is fair to say that there should be a little allowance made for it.

Q. Would it make any difference in the speed with which the boat moves?

A. Yes, it would make a little difference in the speed; still, by the same terms that would be very small. I would not go much on that for this reason: that your displacement in the water would be greater, and you would burn extra coal to make up for that displacement in the water, so that you could not count it both ways, you know.

Q. What is the widest beam of any of the lake carriers with which you are familiar?

A. Sixty feet is the greatest beam that we have at the present time. I have heard of one or two being projected wider, but not built yet. They have only been built within the last three years.

Q. Taking the 600 boats that you mentioned as being owned by members of your Association, 70 per cent. of which, you say, would be affected by the lowering of the water at the critical points—

A. (Interrupting.) At Ballard's Reef.

Q. At Ballard's Reef, do all of the boats included in that 70 per cent. navigate through the Detroit River?

A. Do they go through the Detroit River?

Q. Yes, on all their trips?

A. Well, perhaps, not; the largest portion do, but there is some that would not for this reason: you take a boat, for instance, going from Lake Superior to South Chicago, she does not come down the river at all.

Q. And she would not be affected by any change in the level at Ballard's Reef?

A. She would not be affected, no.

Q. What percentage of the 70 per cent. would you say ply between South Chicago, or any port—

A. I can't answer that question without looking it up; I would not like to answer it. I will look it up.

Q. Have you data from which you could determine that question?

A. Well, I could, so far as our own boats are concerned, I think.

Q. I mean so far as your own boats are concerned?

A. Yes, I think I can.

Q. Will you be kind enough to do so before the hearing closes. I am not particular as to the time but let us know what percentage of the boats do not pass through the Detroit River?

A. It is small as compared to the whole number; but then there is a percentage and I have an impression, but it is only an impression—I do not give it as a fact—I have an impression that in making my estimate of 70 per cent., it would allow for any that might go in the Lake Michigan trade; but that is my impression, not positive about it.

Mr. Wilkerson: Those would be affected by the Poe lock. The boats that come down from Lake Superior to South Chicago would be affected by the level of the water in the Poe lock?

A. Oh, yes, of course.

Q. As I understood you a moment ago, now the water is lower there than it is at these other critical points that you testified to?

A. Yes, sir.

Q. Eighteen and eight-tenths at the Poe Lock?

A. Yes.

Q. And 20 at Ballard's Reef?

A. Yes; just a shade less than that. We call it 20 feet.

Mr. Williams: Mr. Livingston is going to give us some figures and my suggestion is that we stop here. I do not think of anything more I wish to cross-examine him about except on those points, but I would like to reserve the right to ask him some further questions when he brings in that information.

Mr. Wilkerson: Certainly. You may reserve your right to question him further.

Re-direct Examination by Mr. Wilkerson.

Q. Coming back to this question of freight rates and the elements that enter into the determination of those rates, is there anything that enters into that with the exception of these items of cost and interest, cost of operation and allow-

ance to be made for depreciation. I refer, for example, to the fact of railroad rates and competition of that kind. Is that an element that enters into determining what the rate is?

A. No, that would affect the tonnage; it does not affect the general—

Q. I mean, would it affect any trade at all?

A. I must confess I do not think I clearly understand that. So far as the bulk of the carrying trade on the lakes is concerned, the railroad rates practically cut no figure, because we carry freight on the lakes at the lowest rate of freight known in the world. You take railroad freight, for instance, roughly speaking about the lowest estimate that I know of that has been made anywhere, and that is when the Lake Shore was publishing rates, these rates, I think they were about—the lowest freight rate that I know of now on any railroad is about four-tenths of a cent per ton per mile, about that. I do not give it exactly. And you see we carry freight on the lakes now for about seven-tenths of a mill per ton; so that there is no place in the world where freight is carried so cheaply as it is on the Great Lakes. The package freight lines, they would carry in competition to some extent with the railroads; but as a rule the package freight lines are owned by the railroads, and so they take their mileage *pro rata* out of whatever the rate would be. I would have to qualify that to a little extent; it would affect a little the grain rates, but we always carry it so much cheaper that it does not affect us seriously. It would, of course, if the railroads would go in, as they have done sometimes in Chicago, when they wanted tonnage they would go in just before the opening of navigation; they used to make a practice of that but they have not gone into that so much lately; they would slaughter a rate and make a low rate for the sake of moving a lot of the grain before navigation. But Chicago has ceased to be the great grain port that it used to be.

Q. Directing your attention to the line of questions relating to the lengthening and widening of the vessels that are engaged in commerce on the lakes, is it a fact that a vessel might be made longer and wider and yet not be understood as affecting in any way what you have stated with reference to the loss to commerce, by reason of diminishing the depth of the water in the channels and harbors?

A. I do not know that I get that quite clearly.

Q. (The question was read to the witness.)

A. Every inch you lowered the water would be a loss to

commerce, of course, because you would reduce the tonnage you carry. For instance, everything that is done now is done with a view to the future. Here is the new lock at the Sault that the government is building now.

Q. That is to say, without regard to how long or how wide you may construct vessels—

A. Not at all.

Q. The loss by reason of being unable to make the draft more than so much is always there?

A. Well, that is evidenced by the fact we are going to get more water; that is beyond a doubt, because here is the new lock at the Sault that is to be 1,350 feet long, 85 feet wide and 24½ feet on the mitre sill, based on a depth of water of 601.5 at New York, ocean level.

Q. You spoke about accidents to vessels being covered by insurance, that is to say about the loss resulting from accidents being covered by insurance?

A. Yes, sir.

Q. I assume it is not the practice, is it, to have an insurance which covers the lost time?

A. Oh, no, no.

Q. That always remains?

A. No insurance covers lost time; there might be a case arise, which Golden explains better than I can, a vessel might do this: in case she had a collision and the other vessel was found to be at fault, she would be able to charge demurrage for the time she was out of commission.

Q. But that has nothing to do with insurance?

A. Oh, no, nothing covers delay of that kind, nothing at all.

Q. So that in addition to the loss to the vessel because of the accident, there is always the lost time?

A. If a boat goes aground and she loses a week getting off, that is gone; she loses that utterly, or if by any other accident she loses time, no matter what the accident may be.

Q. Coming back to the question of construction again, what do you say about the strength of a vessel which is 600 feet long, which draws 20 feet, as compared with one of the same length which draws 30 feet?

A. I do not see any difference in them; the boat that is built to draw 30 feet, she is built under specifications required to give her a rating of Lloyd's 100, as they call it. That is a standard classification that is used on the other side of the water, that we have adopted over here largely. And so, allow-

ing for the difference in depths, etc., the longer you build the vessel as a rule, the greater depth you make her hold.

Q. Precisely, and it is a fact recognized in connection with the construction of vessels, is it not, that the long, shallow vessel is not so strong as the one of greater depth?

A. No, sir, she is not.

Q. The vessel which has the greater draft is the stronger vessel?

A. That is assuming, that is true—

Q. It is stiffer, isn't it?

A. A stiffer vessel, oh, yes. You take the shoaler vessel, if they build her right, they should put in some compensation, but the deep draft boat has the advantage. That is the reason that many of our boats now could draw several feet more water than they do; on account of that it gives extra strength, depth of hold.

Q. Counsel on the other side asked you some questions with reference to the effect of increasing the cargo on the amount of coal that it would be necessary to consume. Suppose you increased the cargo 1 per cent., would you have to increase the amount of coal which you burned 1 per cent.?

A. Oh, no.

Q. That same thing would apply to what you said about speed?

A. That would be about at the proportion.

Q. Does the same thing apply to the effect, if any, on the speed of a vessel; if you increased the cargo 1 per cent., would it have that effect on the speed?

A. In other words, supposing you carried a given number of pounds pressure; let us take a unit. If you had a boat that was carrying we will say 200 pounds of steam and she was drawing 19½ feet and then you load her to 20 feet and carried the same steam, same revolutions, it would not make as good time; you would have to accelerate your turns and burn a little more coal to get it, but the proportion would be very small as compared with the increased cargo.

Mr. Wilkerson: I think that is all until after you bring in the data in response to the request of counsel for the defendant.

Recess to 1:30 p. m.

May 24, 1909, 1:30 p. m.

CHARLES KELLER, a witness called on behalf of the Government, was first duly cautioned and sworn and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name, please?
A. Charles Keller.
Q. Where do you live?
A. I live here in Detroit.
Q. What is your present occupation?
A. I am Major of the Corps of Engineers U. S. Army; and I at present have charge of the office of the United States Lake Survey; that of the Engineer of the Eleventh Light House district, and of the United States Engineer office at Grand Rapids.
Q. What have been your preparation and what has been your experience in work as an engineer?
A. I am a graduate of the Military Academy, and of the Engineering School of Application. Since 1893 I have been engaged in the work of river and harbor improvement. In more recent years, I have been in charge for two years of the harbors upon the east shore of Lake Michigan. I have had for four years charge of the office of the Engineer of the Eleventh Light House District. I have been in charge of the office of the United States Lake Survey for two years; and I was for two years in charge of the rivers and harbors upon Lake Huron.
Q. Have you had anything to do with hydraulic measurements on the Great Lakes, if so what?
A. Since May, 1907, I have been in charge of the office of the United States Lake Survey which, since that time, has made hydraulic measurements upon the Niagara, St. Clair and St. Lawrence Rivers.
Q. Having in mind your experience as an engineer, what have you to say as to the effect of diverting a given quantity of water, as for instance 4,000 cubic feet per second, from Lake Michigan at some point, for instance Chicago, the effect, I mean, as to the lowering of the level of the Lakes?
A. In my opinion it would unquestionably lower the levels of Lakes Michigan and Huron; and all the connecting rivers and lakes below there.

Q. Would that effect be general and uniform?

A. It would be uniform over the entire chain of lakes with the exception of Lake Superior, which would probably not be affected.

Q. That is to say if there is a certain definite lowering at any one point, that lowering would be general?

A. It would be general, although not precisely the same amount on all the other lakes and on the rivers.

Q. When you speak of the term, lowering the level of the lakes, are you speaking of that in an absolute sense? By that do you mean as a matter of fact the level of the lake would be lower, or do you mean it would be lower than it would have been if there had not been the diversion at Chicago?

A. It would be lower than it would have been had there been no diversion at Chicago. As a matter of fact, natural conditions might be such as to obscure the natural effect of any diversion at Chicago.

Q. Where are the outlets of Lakes Michigan and Huron, Major?

A. In the St. Clair River, whose head is at Port Huron, and it discharges into Lake St. Clair.

Q. If you take water out of the lake at Chicago, what is the effect of that upon the quantity of water which goes out through the St. Clair River?

A. You eventually diminish by precisely that amount the outflow of the St. Clair River.

Q. What do you mean by the term "net supply" as it is used in connection with the water in the lakes?

A. The net supply which is in effect the discharge of the outflow rivers, is the difference between the precipitation upon the Great Lakes and upon the drainage basin tributary to the Great Lakes, and evaporation and other losses, such as percolation. In other words net supply is precipitation minus evaporation and minus other losses.

Q. Having in mind the elements which go to determine the level of the lakes at any given time, what is the relation or connection between rainfall, evaporation, absorption and runoff, and the water which would be diverted at a given point, say Chicago?

A. There is no connection whatever between them.

Q. That is to say, would the diversion of the water at Chicago have any effect upon any one of these other elements?

A. Oh, yes, it would. I misunderstood you. It would af-

fect the runoff eventually. It would not affect rainfall, nor could it affect evaporation.

Q. The only thing it would affect would be the quality of water that went out through the St. Clair River?

A. Yes, the net supply as we have called it.

Q. By that you mean this: the quantity of water which is in the lakes and the resulting level is the product of a number of different elements. If you divert a certain quantity of water from the lakes at Chicago, is that an element which would affect the level of the lake, that is have an effect upon the level of the lake, independent of these other elements?

A. It certainly would.

Q. Would that always be present as a controlling factor?

A. It will always be present as one of the factors which control the ultimate level of the lakes.

Q. I am about to show you some charts which indicate the relation between the quantity of water which flows out through the St. Clair River and the level of Lakes Michigan and Huron; also charts which have to do with the outflow from other lakes and the level of the water in those lakes. As preliminary to that, I would like to have you explain in a general way, Major, how you would proceed to determine the relation which exists between the level of the lakes and the outflow from the lake, and how you would proceed to determine the effect upon the level of the lakes of diverting this water at Chicago. State first whether it is possible to determine what that effect would be, and if it is how you would go about determining it.

A. The effect is determined by the process of making what are termed discharge measurements. The object of the measurements of a discharge at any given time is to determine what the flow of the river, whose discharge is being measured is, at the time that the discharge is being taken. When the discharge is measured, close observation is also made of the level of the lake from which the river flows.

Q. If I may interrupt you, how do you make those measurements which determine the quantity of water that flows out through the river?

A. The general process in use by the Lake Survey, and in general use everything for the determination of the discharge of a large stream is that of measuring the flow by means of current meters at a section, cross-section of the river, at a point on the river that has been selected because

of its fitness for this purpose. A section is fit for discharge measurements when the conditions of flow are uniform, steady; when the cross-section itself is deep and fairly uniform in depth; when the flow approaches at a good velocity say in the neighborhood of 4 feet or more per second and leaves it with a fairly good velocity; and when the conditions above and below the section are such as to indicate that the flow itself is steady and appropriate.

Q. Just what is a current meter, how is it operated in practice?

A. A current meter is an instrument of precision, in our opinion, which consists roughly of a wheel or propeller which is set in motion by the movement of the water in which it is immersed. The revolution of this wheel is indicated at the surface of the water through an electric current, which is alternately made and broken by means of contacts upon the shaft of this propeller. It is indicated at the surface of the water upon a register which is part of the machine. This register is merely a counter and discloses the number of times the propeller of the meter revolves in a given length of time, given number of seconds, to be accurate. As the meter is intended to measure velocity, it becomes necessary to express in a definite formula the connection between speed or velocity of the water and the number of revolutions of the meter wheel. This is done by means of rating operations in which the meter itself, in place of remaining stationary in the water, as it does when a discharge measure is being made, is drawn through the water at known velocities. That is, known velocities are recorded and are varied sufficiently to obtain what is known as the rating equation of the meter. From this rating equation and the curve which results from the rating equation, it is therefore possible, having the number of revolutions which the meter makes in a given period of time, to derive directly the velocity of the water which has caused these revolutions. Having used the meter in this fashion, in accordance with a program which has been definitely fixed as being sufficient to obtain the information which is necessary with respect to all portions of the cross section, from the meter registrations and the record that is made of them, and from the record of the levels of the controlling lake, we are enabled to plot diagrams which show the relation between lake stage and lake discharge, river discharge, and from this, in general terms, we are enabled to derive a law which is probably the law of discharge of the river whose measure-

ments we have been taking. I can go into further detail if you want, but I do not think it is material.

Q. I wish only the statement of the general process leading up to the plotting of these measurements and these charts, and the drawing of the line expressing that relation. I direct your attention to a map or chart which has been already marked in this case "Complainant's Exhibit No. 1, 2/15/09." Have you seen that before?

A. Yes, I have seen it before.

Q. What have you done in connection with determining the formula that are expressed on that chart, with reference to determining the accuracy of the line which is drawn there, expressing this relation between the stage of the lake and the outflow through the St. Clair River?

A. From a personal investigation of the method in which the discharge measurements of 1899 and 1902 were conducted, and from a personal knowledge of the methods which were pursued in 1908, I know that the measurements as platted upon this diagram represent with the highest attainable degree of precision the actual outflow of Lake Huron, at the time when the discharge measurements were made. And I believe that the straight line which is drawn through the platted points represents as nearly as any line may represent, the law which governs the outflow of Lake Huron, or the flow of the St. Clair River.

Q. To go a litle more in detail into what is shown on this chairt, I direct your attention particularly to the formula at the bottom of the chart and to the scale which is out at the side of the chart?

A. Yes.

Q. I will ask you first to explain the formula and then to state the fact with reference to the correctness of what is indicated on the scale there at the side?

A. An examination of the drawing itself shows that for a change of one foot in the level of Lake Huron, the discharge or outflow changes by 23,820 cubic feet. This same law is expressed in algebraic or mathematical language in the legend in which is the equation: delta H=delta Q divided by 23,820. That states in mathematical language what I have just described in ordinary terms. This equation means that for any given change in discharge in the St. Clair River expressed in cubic feet, the change in height of Lake Huron expressed in feet will be that change in discharge divided by 23,820.

Q. What name do you give to that figure, 23,820?

A. We have called it the increment, increment of discharge.

Q. Increment of discharge means what, to state it in simple language?

A. It is the change in discharge for one foot change of a stage in the controlling lake.

Q. How is that increment obtained?

A. By direct measurement from the line which is drawn on the diagram, by measuring the horizontal distance on the scale, which corresponds to a vertical distance of one foot, we get what is called the increment of discharge; and this has actually been done on the diagram which appears here.

Q. Now carrying out the conclusion from the line as there drawn and from the formula as you have explained it and from this increment of discharge as you have explained it, what is the fact shown with reference to the lowering of the level of Lakes Michigan and Huron for the diversion of 5, 10, 15, 20 thousand cubic feet?

A. The scale at the side which appears to be correctly drawn shows that for a reduction in outflow of 5,000 cubic feet per second there will be a reduction or lowering of level in Lake Huron of a trifle over 2½ inches.

Q. And the effect of the diversion of 4,000 cubic feet at Chicago would be what?

A. Practically two inches, as shown by the scale.

Q. And for 10,000 cubic feet?

A. For 10,000 it would be a shade over 5 inches; for 15,000, it would be a trifle more than 7½ inches, and for 20,000 it would be slightly more than 10 inches.

Q. Now keeping in mind your experience in connection with these measurements and observations, what have you to say with reference to the accuracy of the conclusions based upon the platting of these observations, and upon the formula which you have just explained?

A. I think that in all probability the results that I have just given are accurate within approximately 5 per cent.

Q. Can you, without going through any long mathematical process, state why you put that at 5 per cent? What is the reasoning in your mind that leads you to say 5 per cent?

A. Well, as a general rule, we have found out in our discharge measurements that the line which most nearly expresses the law of discharge will be so drawn upon a diagram that the extreme measurements, those which diverge furthest from the line, will contain an error not to exceed

about 2 per cent. That in itself is probably an error that does not altogether measure the total error which appears in the measurement. It shows the internal or relative consistency of the measurements, but it does not exhibit the fact that it is possible that in addition to small errors due to the use of the meter itself, there may appear small errors due to the impossibility of measuring the cross section with absolute accuracy. And the final result will also show a very small error due to the slight errors of gauge readings, that may appear in the result. And while I have said 5 per cent., it is merely my opinion that the final result may show an error as large as 5 per cent. I do not believe it will show anything larger. I think all causes combined would probably aggregate at the very utmost 5 per cent.

Q. You have, in your study and investigation of this subject, had occasion to read what engineers, men in your profession, have had to say about the relation between the level of a lake and the quantity of water which flows out from it?

A. Yes.

Q. What is the fact as to its being generally accepted as something that is practically axiomatic, if you can use that term, that there is some relation between the level of the lake and the quantity of water which flows out through the river?

Mr. Williams: Let the record show that I object to the question first on the ground that it is leading; in the second place that it is calling for the opinions of others than the witness himself?

A. I have never known of any engineer who has disputed the general axiomatic proposition that the discharge of the outflow rivers varies directly with the height of the lakes themselves; increasing as the lakes rise and diminishing as the lakes fall.

Q. The only question then remaining for determination is as to the——

A. The quantity of change of discharge with a given amount of change in level.

Q. I understand you to say you have never known an engineer to question the general fact that such a relation does exist?

A. I never have.

Mr. Williams: I wish to note an objection to that question as a statement of counsel and not a question.

Mr. Wilkerson: Q. And further, that there may be no question about it: how generally have you given considera-

tion to what has been said on this subject; have you covered a good deal of ground?

A. I answer your question as generally as you ask it; I think I have read everything that has been written on the subject of the levels of the lakes as connected with the discharge of the connecting rivers. So far as I know there is nothing that has ever been written that I have not read, with greater or less care.

Q. Have you read everything you have heard of on the subject?

A. Yes, I have read everything that I have heard of.

Q. And what you have just said, the statement you have just made, is based upon that study?

A. It is a summary of that study.

Q. Now, what is the effect of the lowering of the waters of lakes Michigan and Huron upon the water in the St. Marys River, at the foot of the locks?

A. There is a lowering at the foot of the locks, but it is less in amount than the lowering of the lakes themselves.

Q. As a result of your study and investigation, are you prepared to make a statement with reference to the percentage of lowering there would be in the St. Marys River at the foot of the locks?

A. No, I am not prepared to make a precise statement.

Q. Suppose that Lakes Huron and Michigan were lowered a certain definite amount, and Lake Erie a certain known amount, what would be the lowering in the Detroit River and Lake St. Clair and the St. Clair River?

A. The lowering of the St. Clair River, of Lake St. Clair and of the Detroit River at various points would depend directly upon the amount of lowering on Lakes Huron and Erie. Lake St. Clair, or the level of Lake St. Clair, is directly connected with the level of Lake Erie by means of an equation, which if you desire I am prepared to give, as derived from the investigation of the Lake Survey.

Q. I would like to have you give that.

A. The height of Lake St. Clair at the Flats is $h—.602 H+.373h'$ times plus h' times .373. Small h will give the change in elevation of Lake St. Clair due to change of H in Lake Huron and h' in Lake Erie. If there is a change of a foot in each lake, the change in Lake St. Clair would be .975 in feet. The change in the St. Clair River between the head of the river and Lake St. Clair would vary from the full amount of the change on Lake Huron down gradually to a

limit which is set by the amount of change of the St. Clair Flats gauge. In the formula or equation above, h equals St. Clair Flats gauge, minus 575.12; H equals Harbor Beach gauge, minus 580.70; h′ equals Cleveland gauge, minus 571.96.

Q. That is to say at any one of the critical places of that change, the Detroit River or Lake St. Clair, the lowering would be some place between the total lowering of Lake Huron and the minimum?

A. And the corresponding change on the other lake.

Q. Which you have given?

A. Yes.

Q. How exact, in your opinion, is that statement that you have just made?

A. For any given change in Lake Huron and Lake Erie it is probably at least 10 per cent. wide of the truth; but for a long period of years it will come pretty close to expressing the average elevation of the St. Clair Flats gauge.

Q. I direct your attention now to a chart which has been marked "Complainant's Exhibit No. 2" under date of February 15, 1909, the same purporting to show the loss of level in the St. Lawrence River at Ogdensburg, corresponding to loss of outflow by reason of the diversion at Chicago. I will ask you to state whether or not you have examined that before; if so what examination you have made of it?

A. I am familiar in a general way with the processes by which this diagram has been derived, and I know it to be based upon actual discharge measurements made in the St. Lawrence River. And I further believe from examination that the line which represents the law of discharge of the St. Lawrence River is the probable law as based upon discharge measurements actually made.

Q. If water is diverted from Lake Michigan at Chicago, what effect does that have upon the outflow of the Niagara and St. Lawrence Rivers?

A. Reduces by precisely the same amount eventually the outflow of the Niagara and St. Lawrence Rivers.

Q. Why do you say that?

A. Because the outflow of these two rivers consists only of the surplus waters of the lakes. If anything is taken away from those surplus waters of the lakes up above, it is necessarily taken away from the outflow of these rivers.

Q. The formula and the increment is derived from the same process as the one that you have already explained?

A. As in the case of the St. Clair River, except that the

increment in the case of the St. Lawrence River is 28,870 cubic feet per second for a change of one foot in the elevation of Lake Ontario.

Q. And what result does that give as to the effect of the diversion of say 4,000 cubic feet at Chicago from Lake Michigan?

A. The resulting changes are somewhat smaller than they are on Lake Michigan and Lake Huron. For 4,000 feet, the lowering of Lake Ontario and the upper St. Lawrence River is about 1.6 inches.

Q. I show you two other charts which have been marked Exhibits 3 and 4 respectively of the same date as that given in connection with the charts already in evidence. No. 3 relates to the loss of level in Lake Erie corresponding to the loss of outflow in the Niagara River, and No. 4 relates to Lake Erie also; one being the International Bridge section and the other the Open Section. Will you take those two charts and state what investigation you have made of the matters to which they relate, and explain to us the result as shown by the charts?

A. I am familiar with the diagram concerning the discharge measurements at the International Bridge section, and I know personally concerning the discharges which were measured in 1907 and 1908, as these were taken during the time of my being in charge of this office.

Q. That is to say those measurements were measurements made under your direction?

A. Made under my direction in 1907 and 1908.

Q. And with your knowledge?

A. And with my knowledge.

Q. Go ahead?

A. The line which appears upon the diagram is in my opinion correctly drawn from the platted discharges, and represents the probable law of discharge of the Niagara River at the International Bridge Section. The diagram shows an increment of 21,900 cubic feet per second for a change of stage of one foot in Lake Erie. The second diagram relating to the Open Section of the Niagara River is based upon discharges which were measured before I assumed charge of the Lake Survey office; but I am familiar with the manner in which the discharge was measured, and I believe that the discharges themselves are correctly platted, and the line which represents the law of discharge correctly drawn: For the Open Section, the diagram shows an increemnt of 21,640 cubic

feet per second for a change of stage of one foot in Lake Erie.

Q. In order to get it in the record, what do those charts show as to the effect of a diversion of 4,000 cubic feet per second at Chicago?

A. They show about the same thing, a lowering of about 2.2 inches, corresponding to a diversion of 4,000 cubic feet at Chicago.

Q. In connection with Lake Erie there are two sections taken, one is the Open Section and the other is the International Bridge section?

A. Yes.

Q. Why were those two sections taken, Major?

A. The measurements at the Open Section were taken in order to verify the measurements previously taken at the International Bridge Section; and as a result they show a very close agreement between the two sets of discharge measurements.

Q. Now coming back to the question which I put to you with reference to the observations of the St. Clair River, as to the accuracy of the result which is based upon those observations, what have you to say as to the accuracy of this result with reference to Lake Erie?

A. I believe that the measurements at the International Bridge Section are considerably more accurate than those of the St. Clair River because of the fact that the cross-section itself gave opportunity for measurements superior to the opportunities which existed in the St. Clair River. The bridge offered an absolutely fixed platform from which measurements could be made, and absolutely fixed the points at which velocity was measured by discharge meters. At the same time, the cross-section itself was an absolutely fixed one. The nature of the bottom material was permanent, so that there could be no great uncertainty as to the area of cross-sections and absolutely no uncertainty as to the points where soundings were made.

Q. With reference to the substantial agreement between the result as shown from the observations at the Open Section and the one at the International Bridge Section, is there anything in that which to the engineer furnishes a basis for reaching a conclusion as to the accuracy of the statement you have made with reference to the general result?

A. It is very strong corroborative evidence of the results obtained at the International Bridge Section. The close agree-

ment must be due to very painstaking and trustworthy methods of measurement. The agreement in the very nature of things cannot be accidental.

Q. In your own mind, and in connection with your own opinion on this subject, has the fact that there is that agreement with reference to these Lake Erie measurements had anything to do with the statement which you have made as to the accuracy of the result showing the relation between the stage of the lake and the outflow through the rivers?

A. Yes, that is one of the principal grounds for my statement.

Q. The measurements on one of these sections was made from the bridge?

A. Yes.

Q. The measurements on the Open Section were made where?

A. Made about 1,800 feet below the bridge.

Q. And without the assistance which would come from making the observations from the bridge?

A. Yes.

Q. Referring again to that substantial agreement between the observations, does that indicate anything with reference to the accuracy of the observations which were made at the Open Section?

A. They indicate that the observations at the Open Section were themselves very accurate.

Mr. Williams: We will agree if the observations on the Bridge Section showed that the observations on the Open Section were accurate, the observation on the Open Section shows that the others were accurate too.

Mr. Wilkerson: Q. In the very nature of things, from which set of observations would you expect the highest degree of accuracy?

A. From those at the Bridge.

Q. Why?

A. For the reason I have already given, that the bridge itself was a more favorable cross-section for measurement than an ordinary open section can be.

Q. Coming back again to the thought just suggested by the counsel on the other side, having the observations on the bridge, with this element of greater accuracy present for the reason which you have stated, does the agreement that results from those observations and the ones at the Open Section furnish a foundation for making a statement and

forming an opinion with reference to the accuracy of the observations at the Open Section?

Mr. Williams: I object to the question on the ground it is leading; on the ground it is furnishing the witness with additional reasons for the testimony he has given already; and on the further ground that he has already answered the question several times.

A. I understand you to ask whether the agreement between the results at the International Bridge and those at the Open Section gives additional reason for believing in the high degree of accuracy in the methods used at the Open Section?

Mr. Wilkerson: Yes.

A. Yes, it does. It is the only independent evidence we have.

Q. On this same general subject of the correctness of results which are reached through the method which you have described, are you familiar with the measurements on the Niagara River, which were made by the Deep Waterways Commission in 1897 and '8?

A. Yes, I am.

Q. Those were the measurements made by the United States Board of Engineers on deep waterways. You are also familiar with the recent measurements which have been made on the river?

A. Yes.

Q. How do the recent measurements agree with the measurements of United States engineers on deep waterways?

A. For any given stage of discharge as published in the report of the United States Board on deep waterways, the figures are from ten to twelve thousand cubic feet per second in excess of the figures which we now give as being correct. And the reason for that discrepancy appears to have been that while the measurement of velocity made by the Deep Waterways Board was as accurate as anything that we do nowadays; that the soundings taken in ascertaining the area of cross-section were by no means as accurate as the later soundings, those of 1898 and 1899 being made with far higher degree of precision.

Q. Are you familiar with the measuremnets that were made by one Quintus in 1891 and '2?

A. I have read his published reports.

Q. Who was he?

A. He was assistant engineer; he is an assistant engineer in the employ of the United States Engineer Office at Buffalo.

Q. With reference to his measurements on the Niagara River, how do they agree with the more recent measurements?

Q. The agreement is only fairly good so far as concerns discharges pertaining to definite stages, but both his discharge measurements and those of the Deep Waterways Board show a substantial agreement with the Lake Survey discharges. In the derivation of the increment of discharge, the increment of discharge corresponding to a change of one foot in the level of the lake, they all give an increment between 20,000 and 30,000 cubic feet per second for a change of one foot in the level of Lake Erie.

Q. The larger the increment, the smaller would be the lowering for any given diversion, is that right?

A. Yes.

Q. What is the largest increment that has ever been derived from any set of observations that you know of?

A. I think the one of Quintus. That shows an increment of about 35,000, but I think that is an isolated case, and I think the largest increment that has any standing is the increment for the St. Lawrence River which is 28,800, or thereabouts.

Q. That is as high as anybody has ever called it?

A. As high as anybody has ever called it that I know of.

Q. And on these different observations, how low does it go?

A. Well some of the St. Clair increments go as low as sixteen or seventeen thousand cubic feet to the second; that is the lowest any of them have gone.

Q. That is the lowest increment that has ever been derived from any series of observations?

A. From a series of observations, yes.

Q. Going back to the Quintus observations, Major, can you make, after referring to the report, a more definite statement as to his increment?

A. I have here in my hand a copy of Mr. Quintus' results sworn to by him, in which he states the discharge increment per foot at or near mean lake level at 21,000 cubic feet per second.

Q. Now those are measurements on the Niagara River?

A. Yes, sir, made in 1891. And while that statement is

an answer to your question, in explanation of my previous answer I desire to call attention to page 4371.

Q. Make your explanation as clear as you desire.

A. I said in my previous answer his increment varied between 21,000 and 35,000 cubic feet per second. The flow which I have just read you from his report is for mean lake level. For a different stage of the lake, in the printed and published report upon page 4371 of Part 6 of the Annual Report of the Chief of Engineers U. S. Army for 1893 there is a table which shows in the last column a single increment of 35,000 cubic feet. That explains my previous answer.

Mr. Williams: Q. What was the lake level there?

A. He gives the lake level as probably between four and five feet; that would be four or five feet above mean lake level; and I imagine that is a deduction from his curve rather than an actual measurement.

Mr. Wilkerson: Q. So that we will not have to come back to it again, that 35,000 increment I understood you to say it is obvious from the report that it was not based upon actual observations but was a computation based upon the formula for a higher stage?

A. Yes, that is what I believe to be the fact; and I think the curve shows it.

Q. Just find what he says on that subject and read it.

A. I think the answer to your question is given from the table here, the table on page 4367 of the same report, which shows all the discharges which were actually measured, contains no discharge which was measured at a stage corresponding to that for which the increment was previously stated as 35,000 cubic feet per second.

Q. In the light of investigations which have been made subsequent to that time, was there any warrant in attempting to extend a computation with reference to the increment on the formula, to those higher stages which were not covered by actual observations?

A. That is what he has done in this table where he gives this theoretical increment of 35,000 cubic feet. The increment of 21,000 cubic feet is actually derived from the measurements themselves.

Q. Should he have done that?

A. It is not good practice.

Q. In the light of practical experience?

A. It is not good practice, and it is not ordinarily done.

Q. You are familiar with the conditions on the St. Clair River, are you, Major?

A. Yes, sir.

Q. What is the season of navigation on the St. Clair River?

A. I will answer your question as Engineer of the Eleventh Lighthouse District. As Engineer of the Eleventh Lighthouse District, it is my duty as early as possible to send from Detroit completely loaded and equipped the lighthouse tender belonging to that office. During the last four years, the date of despatch of the tender (and that represents practically the opening of the season of navigation) has been as follows: 1906, April 17; 1907, April 16; 1908, April 24; 1909, April 24. During three of those four years, the closing of the season of navigation was coincident with the final date of the last trip of the same vessel, and in those three cases, to the best of my recollection,—I have not verified the exact dates—the season of navigation may be said to have closed in the St. Clair River on or about December 15.

Q. During the winter months there is ice in the St. Clair River?

A. Yes, sir.

Q. What is the effect of that ice in the river upon the outflow of the water from Lake Huron?

A. The effect is to diminish or retard the outflow.

Q. As to this ice retardation, approximately when does it begin and when does it end?

A. In general terms it may be said to begin about the middle of December, and to end about the middle of April, although there have been exceptional years when it has begun earlier and lasted later.

Q. How about May?

A. The year 1901 is a typical year in which there was ice effects shown after the first of May, but as a general rule May is not an ice month.

Q. I wish you would take up this subject of the presence of ice in the St. Clair River and in the Niagara and St. Lawrence Rivers also, and state what information if any you have upon the subject of the effect of this ice retardation.

A. The only information that I have on the subject is derived from my reading of reports of investigations made by the United States Lake Survey into ice effects. The first investigations of that sort were the investigations into the ice effect in the St. Clair River. These investigations

were made late in 1900 and early in 1901, and they showed that the discharge of the St. Clair River measured at a time when the river was in its lower portion sealed by ice was considerably less than the discharge which corresponded to the existing level of Lake Huron. The discharge curve or formula derived from—

Q. I wish you would take up that subject, as the result of your experience and your study, and state just what your conclusion is with reference to that ice retardation; and what is the determination of the government?

A. My conclusion, independently of that of this office, my personal conclusion is that the ice effect is a large but unknown factor in the determination of the levels of the Great Lakes; and that up to the present time the Lake Survey has not made sufficient measurements to enable any one to form a justifiable conclusion as to the measure of the ice effect, either in the St. Clair River, or in any of the other rivers; the Niagara or the St. Lawrence.

Q. Are you familiar with the formulae which have been derived, bearing upon the subject of ice effect?

A. No, I am not familiar with any formulae that have been derived bearing directly upon ice effect.

Q. You have spoken in connection with the determination of the effect of diminishing the outflow through the St. Clair River upon the level of the lake, of the increment; what could you say on the subject of the relation between this ice retardation during the winter months and this increment, with reference to which you have testified?

A. The effect is to diminish the increment.

Q. Why do you say that?

A. Because the increment is the result of the increased head due to a rise in the level of the lake surface. The effect of that head is lessened by the increased friction due to the presence of the ice, or to put it in other words; the efficiency of the cross section when sealed by ice is less than it is when open.

Q. Taking the diversion of the water from the lake, at Chicago, as one element, and the presence of this ice in the St. Clair River as another element, when it comes to the determination of the effect of the diversion of the water at Chicago, is there anything in the presence of this ice in the river during the winter months, which in any way overcomes or counteracts the ultimate effect of that diversion?

A. No. It aggragates the effect of the diversion by in-

creasing the relation which the amount of the diversion bears to the value of the average increment; the increment during the ice months being less, the average increment for the entire year is less than if the river were open for twelve months; and as a consequence the effect upon the lake level is larger than it would be in the absence of ice effect.

Q. That is to say, if I may put the question in this leading way: it has the same effect as if the St. Clair River were smaller?

A. Smaller or narrower or shallower.

Q. Referring to the St. Clair River again, what information have you on the subject of the scouring of the river, as to whether it is changing its regimen or not?

A. During November and December, 1908, I directed that four cross sections in the St. Clair River, which had been permanently monumented or marked at a previous time so that they could be again identified for purposes of measurement, should be remeasured, with a view of finding out what change had taken place in these cross sections, since the previous measurements. The remeasurement was done, as directed by me, and I have here a table, of which Mr. Shenehon will exhibit the original, which shows that at the cross sections which are described in the Annual Report of the Chief of Engineers for 1900 as cross sections Culvert, Fish, Arthur and Stauber, there has been practically no change since the measurements of 1899. That is in a period of over nine years, there has been no measureable change in these cross sections. In cross section Culvert, the measurement showed a scour of about 1.3 feet on the section since 1901. In cross section Fish, there was an apparent shoaling indicated since the previous measurements. In cross section Arthur, a fill of about 2½ feet is indicated since the previous measurement, and in cross section Stauber no change is shown in the area of cross section. These cross sections were in the gorge of the river at its narrowest place, and where scour would be most likely to take place. They are also in what we regard as a critical or controlling portion of the St. Clair River.

Q. Based upon these recent observations then, which have been made under your direction, what is your conclusion as to whether there is any change in the regimen of the St. Clair River?

A. There is no evidence whatever to show any change in the regimen of the St. Clair River. At the same time that these cross section measurements were taken, we made dis-

charge measurements at a new cross section, and we made discharge measurements at a cross section formerly occupied for this purpose; and these discharge measurements were in absolute accord with the measurements that had previously been taken. There exists no evidence upon which to base any assertion of a change in the regimen of the St. Clair River at its head.

Q. About that time, were there any observations made for the purpose of determining the relation between lake level and discharge; that is were these observations used as the basis of any new computation on that subject?

A. The discharge measurements closely accord so far as they go. They were few in number, only thirty-seven in all, but they accord with the previous discharge measurements and are platted in the line of discharge that is exhibited on one of these plates, for the St. Clair River, to show that the law which was formerly deduced for the St. Clair River applies also at these sections.

Q. Is there anything in that that throws light upon the subject of the correctness of the statement that you have made with reference to the increment?

A. It shows that the increment as derived from previous measurements is probably correct and that the law of discharge has been correctly determined.

Q. Since you have been in charge of this work here, have you caused a new section to be measured, for the purpose of corroboration?

A. I have already mentioned that. We established a new cross section at the head of the St. Clair River, above the cross section previously used for discharge measurements. We called it cross section gorge. We had this carefully sounded, and thereafter we took discharge measurements at this new section and these discharge measurements showed discharges which accorded with the discharges deduced from the law here; that is for a given stage of Lake Huron as shown on the gauge, the discharge as derived from Cross Section Gorge corresponds to the discharge which would be taken from the line indicated on the plate.

Q. That is to say, I understand that the practical result of these later observations is in accordance with the law of discharge as it had been already derived from the previous observations?

A. Yes.

Q. What light if any does that throw on the accuracy of the formula which you have given here?

A. Which formula?

Q. On the chart?

Mr. Williams: I object to that. The witness, I assume, in answering the previous questions with reference to the degree of accuracy obtained in making these discharge measurements, took into consideration all the facts that he knew of, and he is testifying to some of those facts now. I object to counsel asking whether each specific item of information confirms the opinion which he has expressed as being the result of all his information.

Mr. Wilkerson: I think it entirely proper for the witness to state any fact or any element which he acted upon in making his statement with reference to the accuracy of the observations.

Mr. Williams: It would be entirely proper for the witness to do that, and for counsel to ask him to state all the facts he took into consideration.

Mr. Wilkerson: I am directing his attention to one specific fact.

Mr. Williams: I object to his attention being directed to every specific item of information.

Mr. Wilkerson: Answer the question.

(The question was here read to the witness.)

A. It affirms the accuracy of the diagram or formula.

Q. What knowledge have you on the subject of the outflow of the Niagara River, as to whether it has been increased or diminished?

A. Alterations in the Niagara River in the vicinity of Niagara Falls, and some slight changes at the head, have tended to increase the discharge capacity of the Niagara River; while on the other hand contraction of the stream above the Canadian Fall has tended to neutralize this effect so that the net result is practically no change in the discharge of the Niagara River, and practically no effect upon the level of Lake Erie.

Q. What is the diversion from Lake Erie into the Welland Canal?

A. I think about 1,200 cubic feet per second.

Q. And into the Erie Canal?

A. That was measured by the Lake Survey under my direction, and was ascertained to be 768 cubic feet per second; the measurement being made in the fall of 1907.

Q. How are those diversions, as compared with what they were before 1890?

A. I believe the Erie Canal diversion is practically unchanged. I am not informed concerning the Welland Canal diversion.

Q. You are pretty familiar with the conditions on Lake Michigan and Huron, I assume, Major?

A. Yes.

Q. That is you have been over them a good deal?

A. Yes.

Q. Now do you know of any outflow from Lakes Michigan and Huron except through the St. Clair River, and what water is diverted at Chicago?

A. I know of none.

Q. What is the generally accepted scientific fact as to that, is there any other?

A. There is no evidence to show the existence of any other outflow.

Q. Suppose there were some subterranean outlet—I put this to you as a hypothetical question—would the fact that the water flowed in or out at a point under the ground make any change in what you have said as to the effect of the diversion of the water at Chicago through the drainage canal?

A. No, it would not.

Q. In other words, would the diversion of that water—

Mr. Williams: I object to the "other words." Let the witness give the other words if there are any.

Mr. Wilkerson: Q. Would that diversion of the water at Chicago remain a fixed factor, which would have the effect that you have indicated upon the level of the lakes?

A. Yes, it would. It has been deduced in view of all facts.

Q. Do you know about the expenditures which have been made in the hydraulic measurements of the St. Clair River?

A. In a general way, I know what time has been spent there and approximately what it has cost.

Q. Let us have a general statement. What I want to get is the extent of the work which has been done, whether there has been much or little, much time or little time spent.

A. Counting the cost of the office reductions as part of the cost of doing the work, I should say we have spent between ten and fifteen thousand dollars in the actual field work of making the discharge measurements. That counts nothing as the cost of the equipment, which is permanently the property of this office, and is used everywhere.

Q. You are familiar with scientific measurements that are made in different departments of research. What do you say as to the maner in which these observations were made, as to the kind of men who made them and the degree of skill and care with which they were made?

A. They were made by men who possessed a high order of engineering skill.

Q. Did they have scientific training?

A. They were men of the highest possible character; men of scientific training, and with a known wish to ascertain nothing but the truth. The measurements were made with no preconceived notions as to what the results should be; and I believe that they are entitled to the very highest credit.

Q. With reference to the measurements on the St. Clair River, take the ones from which these formulae with reference to which you testified are based. Do you know who had charge of that work?

A. Mr. L. C. Sabin, now in charge of the St. Marys Falls canal, had charge of the bulk of the work at the St. Clair River. He is an engineer of the very highest possible standing.

Q. You have had occasion have you to know with reference to his skill as an engineer, and with reference to the kind of work which he does?

A. I know him both personally and professionally.

Q. What would you say on that subject?

A. I regard him as an engineer of the highest possible qualifications.

Q. What do you know with reference to the measurements that were made on the Niagara and St. Lawrence Rivers?

A. Those were made by Mr. Shenehon, who is present. I believe they were honestly and skillfully made, and deserve the utmost credit.

Q. The point that I wanted to have covered, and I think you have covered it already is as to whether it is a fact that all of these measurements and observations were made by men who are men of education in their profession, and men who were trained for this particular work.

Mr. Williams: I object to that question on the ground it is improper for counsel to tell the witness what he desires to have covered in the answer which is about to be made.

Mr. Wilkerson: Answer the question.

A. All the discharge measurements were made by men

who had had a unique training in this kind of work, and who were especially qualified for its performance.

Q. You have come in contact with matters relating to the navigation of the lakes, have you?

A. A great deal, yes.

Q. What have you to say as to whether or not a lowering of the water in Lakes Michigan and Huron, particularly at these points which are characterized as critical points of navigation, to the extent of two inches, would have any real effect upon the navigation of the lakes?

A. I believe it would.

Q. Just what would be the effect? I wish you would explain that somewhat in detail if you can.

A. The draft to which the larger class of vessels may load is directly limited by the depth at what you have called the critical points; that is by the depth at the shallowest places upon the route which they must pursue from their point of departure to their port of destination. In the case of vessels which must pass through the Detroit River, the critical point is at and above the Lime Kiln Crossing. As a matter of fact I know, from my contact with vessel men, that ordinarily they load to the last inch which may safely be carried over these critical points, and that is natural, with a view to earning as much as possible upon each cargo carrying trip. Any reduction in depth at these critical points, therefore, results in a corresponding reduction in the amuont of cargo which may be carried; and the effect is doubly bad because the reduction in the depth of the cargo itself, the depth to which the vessel is loaded, is made at a point where the vessel has the greatest capacity; that is in the upper part of the vessel where it is ordinarily built square, practically like a box. So that a loss of depth has a maximum effect upon earning power. From my frequent conversations with vessel owners and vessel navigators, and personal investigation as to the capacity of cargo carrying vessels, I have ascertained that an inch of draft for the larger class of vessels corresponds roughly to a capacity of 75 tons. So that a loss of two inches in depth of loading is the equivalent of a loss of 150 tons of profitable cargo.

Q. In making the statement that you have made as to the substantial effect upon navigation of this reduction in the quantity of water at these critical points, have you had in mind and given consideration to the fluctuations in the lakes which take place from time to time?

A. I have had those in mind and I know, as a matter of fact, that vessel men are very observant in watching the change in lake levels; the seasonal change is one that they take very close account of, and one which they allow for in their loading. The uncertain changes, those which may be due to barometric effects, they take no account of. Vessels are frequently hung up, as they say, waiting for water at the mouth of the Detroit River, due to what are purely temporary barometric effects. But any reduction due to diversion would be a permanent loss of depth, and would be added to the disadvantages which now arise from the natural fluctuations on the lakes. Such a loss they would have to allow for constantly in the transaction of their business.

Q. In outlining the scope of your present duties, what district was it you said you had charge of?

A. The Grand Rapids Engineer District.

Q. That brings you in contact with navigation on Lake Michigan?

A. On Lake Michigan. It includes all the harbors on the east shore of Lake Michigan proper, with the exception of the harbor of Michigan City.

Q. You spoke of the effect of this permanent lowering at these critical points of navigation of two inches. Are you able, as the result of your observation, to give any specific cases in which vessels have been damaged or where they have grounded, where the injury would not have occurred, if there had been two, four or six inches more of water than there was?

A. There was recently a case of exactly that sort at the harbor of Ludington.

Q. Explain that to us, so that we can see the effect of that, will you, Major?

A. The harbor of Ludington has an authorized depth, that is the depth which we are permitted to create under the law is 18 feet; and ordinarily there is a channel from Lake Michigan into the inner lake at Ludington, which is the harbor of Ludington proper, which affords a depth of fully 18 feet. During the month of April, however, we had a great many southwesterly storms, and as a result of shifting sand, which prevails in the neighborhood of Ludington, and in fact all along the east shore of Lake Michigan, as far north as Charlevoix, at about the middle point between the piers, there was created a very small shoal upon which the minimum depth was found to be 17.2 feet. Now this shoal occurred

between storms, and before the fact of its existence was officially known a vessel loaded with coal, which had come from Buffalo and carried a cargo for the salt works at Ludington went aground in the channel between the piers. Her draft was less than 17 feet forward and a trifle less than 18 feet aft. She remained aground at that spot between the piers, that I have described, for between two and three days. In order to release her, it was necessary to bring the government dredge Gillespie from Frankfort, which is a little over 50 miles north of Ludington, down to Ludington, and pump away a little of this sand, dredge away that sand; and as a result of less than two hours' dredging the steamer was released, entered the harbor, unloaded her cargo and returned to her port of hail to be reloaded. Had there been two or three inches more of depth upon that slight shoal, unquestionably the vessel would have been able to pass over, because the sand was not very compact, and there was not very much of it as was shown by the fact that the dredge by removing less than a thousand yards was able to release the vessel. I think as a matter of fact the dredge moved something like 600 yards before the vessel came off and proceeded into the inner lake.

Q. Would the effect of this proposed diversion at Chicago be felt at Ludington harbor?

A. Yes; not only Ludington, but every harbor on the east side of Lake Michigan, because all of them are in very much the same condition; they have no more depth than they need. Muskegon is a parallel case, where vessels are constantly running aground, due to the lack of merely a few inches.

Q. As a result of your experience in charge of the district with reference to which you have just testified, have you had occasion to give any consideration to the effect upon vessels of introducing a current into a river?

A. Not in that district, I have had no direct contact with the matter of current there.

Q. Where have you ever come in contact with that?

A. Never practically except in the St. Marys River, where in my official journeys as light house engineer I frequently observed that in the large class of vessels the existence of a current of any extent makes the handling of the vessel a great deal more difficult and leads to a great many accidents.

Q. What is the effect upon the tendency to accidents?

A. Oh, it increases largely the tendency to casualties. The worst place upon the St. Marys is known as the Dyke; it is

in what is known as the Middle Neebish Channel, and the trouble there has always been produced by the existence of a very swift current.

Q. You have not had occasion from observation then to know about the effect of the current in the Chicago River with reference to damage to vessels there?

A. Not from direct observation. I am familiar with the facts as generally reported in the annual reports of the Chief of Engineers and as stated by mariners, vessel owners and engineer officers who are familiar with the facts.

Q. Are those facts substantially the same as you stated?

A. Substantially the same; that the presence of a current is a great disadvantage to the navigation of large vessels.

Q. I show you a chart here, which I will ask to have marked Exhibit No. 5 of this date. Tell us what that is, Major, and what you had to do with its preparation, and what it indicates?

A. The chart is a series of diagrams which exhibits the monthly mean water levels of the Great Lakes, as taken from the records of the office of the United States Lake Survey, since January the 1st, 1860. The curves are directly drawn from the measured ascertained levels of the Great Lakes, as derived from gauges upon those lakes. Personally I have had to do with the preparation of these diagrams since early in 1907. It has been republished twice since I have had charge of the Lake Survey office, and in each new edition there has been an addition of the results of the preceding calendar year. We add annually the results of the preceding year to complete it.

Q. You made a like addition each year?

A. Yes. This diagram shows results to January the 1st, 1909. The next edition of this hydrograph will be published early in 1910, and will incorporate the results derived from our gauges for the year 1909.

Q. With reference to the effect of this diversion of the water at Chicago, I omitted to ask you with reference to the effect at different points on the Niagara River. What have you to say on that?

A. The investigations of the Lake Survey made under my direction in 1907 and '8 show that for a foot of fall on Lake Erie the corresponding fall at Black Rock is about .89 of a foot; at Chippewa, it is about a half a foot, and at the Crest of the American Fall it is about $\frac{1}{8}$ of a foot. At intermediate points, it varies in proportion to the values that I have al-

ready stated. I can give more definite values if you wish them, from actual measurements.

Q. I wish you would give that value.

A. The lowering at Austin Street, Buffalo, is .821; at Chippewa .557; Grass Island .556; Willow Island .422; Prospect Point .126; Terrapin Point .238; West end of the Horse Shoe fall .600; at Suspension Bridge it is 2.29 feet, and at the Whirlpool 2.47.

Q. Going back to the measurements which were made by what you have called a current meter, do you know whether or not any tests have been made for the purpose of determining how accurately those meters measured?

A. Yes.

Q. Were they made in connection with your work here?

A. No, the tests were made by this office but before I assumed charge of it. They were made in 1906; I assumed charge of the office in 1907.

Q. Without going into the details as to the results which are shown, I wish you would tell us in a general way how those tests were made?

A. The tests were made in the Detroit River, a short distance below here upon a measured base of 200 feet. At the upper end of the base, about a foot below the surface, a water meter was suspended, and at the lower end of this base another meter was suspended, and the records of both meters were taken. At the same time there was released above the upper meter and suitably timed upon this base, a series of globules, or globes of colored water. These were injected into the stream with a syringe, and it was found that they preserved their form in well defined fashion for the entire length of the base, so that the exact moment of their crossing the upper end and the lower end of the base line could be timed. As a result, the actual velocity of the water could be derived from the velocity of these colored balls of water, and compared with the velocity as derived from the current meters themselves, suitably rated. The tests were, I believe, about seventy-two in number.

Q. Who had charge of the details of the tests?

A. Mr. Shenehon who is present.

Q. And who will be able to give the facts in detail with reference to that?

A. Yes.

Q. Generally what was the result?

A. A practically exact correspondence in velocity, as meas-

ured in the water itself and as measured by the current meter; the only difference existing in the third place of decimals for the average. I mean that the velocity was less than three feet, it was about 2.9 feet, and the difference as measured was in the third place of decimals.

Q. For what purpose were those tests made; that is to say, what connection did they have with the Lake Survey work?

A. There had frequently been made in published articles here and elsewhere an assertion that the operation of rating the meters did not give a true statement of the velocity which the meter was supposed to measure, because the meter when measuring velocity in the stream was stationary and the water moved with respect to it; whereas in rating the meter, the meter was drawn through the water and the water was stationary. That is to say the effect of the water on the propeller wheel of the meter must necessarily be different because of the difference in the two sets of conditions. And these tests were made to ascertain what merit there was in this statement. The result showed there was no merit whatever in the contention.

Q. What did I understand you to say the test showed?

A. The test showed that the velocity derived from meter measurement upon discharge work actually determined the velocity of the water.

Q. That was from a series of how many observations?

A. I think it was seventy-two. It was over seventy.

No cross-examination.

Recess to May 25th, 1909, at the hour of 9:30 o'clock a. m.

May 25, 1909, 9:30 o'clock a. m.

SHERMAN MOORE, called as a witness on behalf of the Government having been first duly cautioned and sworn, testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name?
A. Sherman Moore.
Q. Where do you live?
A. 316 Lincoln Avenue, Detroit.
Q. What is your occupation or profession?
A. I am a civil engineer.
Q. Where were you educated?
A. At the University of Wisconsin.
Q. When did you graduate?
A. I graduated in 1902.
Q. Do you hold any degrees?
A. I have the degree of Civil Engineer given in 1907 by the University of Wisconsin, in addition to degree of Bachelor of Science given at graduation.
Q. Any other?
A. No, sir.
Q. What has been your experience as an engineer, what work have you done?
A. I have been employed by the Lake Survey since June, 1902, on survey work, on triangulation; and during the past three years almost exclusively on hydraulic measurements.
Q. Have you had anything to do with hydraulic measurements on the Niagara River?
A. Yes, sir.
Q. When did you make those measurements?
A. 1907 and '8.
Q. What kind of measurements did you make?
A. They were measurements of the discharge of the river made from the International Bridge.
Q. Go ahead now and tell us just how you made those measurements and for what purpose they were made?
A. The measurements were made for the purpose of determining the effect on Lake Erie of water diversions at Niagara Falls for power purposes.
Q. How did you make them?
A. The measurements were made with the Haskell cur-

rent meter, observing at the index points established in 1899, 1900.

Q. You say they were made by the Haskell current meter. Describe to us briefly and concisely how you make the measurements with that meter?

A. On the Niagara River we did no coefficient work at all. We observed index velocities, velocities at two or three points in each span, and the reduction was made with the coefficients determined in 1899.

Q. How do you measure this velocity with the meter?

A. In the measurements of the discharge of a river, the procedure is first to divide the river into sections of such a size that the current velocities may be considered as proportional to each other. Ordinarily in an open river of large size, we use about a hundred feet. In that space the transverse curve of velocities, that is the distribution of velocities across the river, is not great; and the velocity at any point in that section may be considered as a percentage of the velocity at any other given point which may be taken as the index for that section. At the International Bridge, there were two and three sections in each span. The water passing in a given time through a section, if it was solidified may be conceived as a solid of which four sides would be planes; that is the surface, the back and the two sides limiting the section under consideration. The front would be curved, depending on the distribution of the velocities in the vertical. That is, the velocity at the surface is not the same as it is at the bottom, and the front would be a warped surface. There is a transverse coefficient coming in to a slight extent. In ordinary work on a river, that curve is so slight that ordinarily it would be neglected. Determining the volume of this solid, if we may speak of it as such, is very similar to determining the volume of any solid of irregular size. We measure the ordinates in a vertical plane through the center of the section, ordinarily. The method employed is the two meter method. One meter is placed at the index point, to which the velocities are later referrd, and the other meter traverses the vertical curve, measuring the velocity at the surface at each tenth depth, and also at the bottom. The two meters are run simultaneously and the results are reduced by considering the velocity given by the traveling meter as a percentage of the simultaneous velocity given by the meter at the index point. In that way the vertical velocity curve may be drawn, platting the percentage velocities with respect to the

percentage depths. The mean ordinate to this curve is the mean velocity; the transverse curve, if it is considered, is obtained by platting the index and sub-index velocities for a large number of measurements, with respect to the distance from either side, and drawing through these points a smooth curve. Then the transverse velocity coefficient for any section, or sub-section, will be the mean ordinate to the transverse curve divided by the ordinate at the index point. The product of the vertical velocity coefficient and the transverse velocity coefficient is the velocity coefficient for the panel. The velocity as measured at the index multiplied by this velocity coefficient gives the mean velocity in that panel. The produce of the area of the panel in square feet as determined by soundings, and the index velocity in feet per second multiplied by the velocity coefficient is the discharge through the panel. The summation of all the panel discharges makes up the discharge of the river.

Q. What was the result of these measurements of the Niagara River that you made at the bridge? I refer now to the determination of what we call the increment, in connection with this matter?

A. The measurements in 1907 and '8 checked almost exactly with the measurements made in 1899.

Q. Do you know who made the measurements in 1899, so that we will have them identified here?

A. They were made by Mr. F. C. Shenehon.

Q. You say they checked almost exactly with those?

A. Yes, sir.

Q. How many measurements did you make?

A. I made 126 measurements.

Q. And when did you commence to make them?

A. The first measurements were made in October, 1907. Measurements were made during October and November of that year, and in 1908, in June, July and August.

Q. You say they checked almost exactly with Mr. Shenehon's measurements. What was the increment as you derived it?

A. The increment at mean stage is 22,000 cubic feet for one foot on Lake Erie.

Q. Did you make any soundings of the Niagara River in connection with these measurements?

A. The section at the bridge was sounded in the first four spans on the American side.

Q. What was the result of those observations?

A. The soundings showed absolutely no change in spans 1, 3 and 4, and a scouring out in span 2 amounting to between 15 and 20 per cent increase in area.

Q. What were the conditions in that span which caused this scour?

A. The bottom, in spans 1 and 2, is a deposit of silt. A short distance above the bridge, prior to 1907, there had been quite extensive dredging close to the shore, and this probably resulted in a slight increase of velocity, which scoured out the span. The bottom in the other spans is bed rock, and showed no change.

Q. A little more in detail about these soundings in spans 3 and 4. Have you the result of your work there?

A. You mean in regard to the results or the method of measurement?

Q. Just what were your soundings on spans 3 and 4? You say they showed no change?

A. They showed no change.

Q. About how deep was it in those places?

A. In span 3 the depth is, mean depth, about 28 to 30 feet; maximum depth of about 36 feet. In span 4 the mean depth is 42 to 43 feet and the maximum depth is 48 feet.

Q. What was the velocity of the water at this place?

A. The velocity was high, ran in the neighborhood of six to seven feet per second.

Q. How did you make those soundings, will you give us the method, Mr. Moore?

A. The soundings were made by means of a cast iron weight, which was of the projectile type, a sphere drawn out into cones on each end, with a wooden tail to hold the nose of the weight in the line of the current. The weight used there was 135 pounds. It was suspended with steel piano wire, a little less than one-tenth of an inch in diameter. This wire was carried on the drum of a reel which rested on the chord of the bridge. The circumference of the drum was exactly three feet, and the depth was determined by the revolutions and partial revolutions of the drum. In spans 3 and 4, the velocity of the current was so great that in order to bring the weight to the bottom in the plane of the section, it was necessary to cause the wire to enter the water about four feet above the line of the section. This was done by a heavy weight, which carried a hook which engaged the sounding wire. The auxiliary weight was suspended from the down stream chord of the bridge, and a guy line was run to the

up stream chord of the bridge, so that the weight and the sounding wire could be pulled back up stream any desired distance. The angle of inclination of the wire did not exceed 18 degrees; it was usually much less. The weight was lowered to the water surface, and the reading of the circumference of the drum was taken with the weight just touching the water surface. Then it was lowered to the bottom, and a second reading on the drum was taken. The weight was then raised just clear of the bottom, and the angle which the wire made with the vertical was measured. The difference between the two readings corrected for the inclination of the wire, was the sounding; gave the depth of the water. It was referred to a fixed plane by the readings of a gauge on the shore.

Q. Did you make any measurements on the St. Lawrence River?

A. Yes, sir.

Q. When?

A. In September and October, 1908.

Q. For what purpose?

A. For the purpose of determining the effect of changes which had been made in the river since the former measurements were made.

Q. Were those soundings?

A. The hydraulic section was sounded, and twenty-six measurements of the flow were made.

Q. What was the result of those observations?

A. The observations showed that the flow of the river had been decreased about 5 per cent for a given stage of Lake Ontario.

Q. What change had been made in the river, the effect of which it was your object to determine?

A. The greatest change was due to the construction of what is known as the Gut Dam. That is a dam between two islands at the head of the first rapids in the river, the Galops Rapids, which was built in 1903, I think, for the purpose of facilitating vessel navigation.

Q. Do you know whether there had been any estimate or computation made with reference to the effect of that dam?

A. Yes, sir, there has been.

Q. Was there any before you made the measurements?

A. Yes, sir.

Q. Based upon this method of determining the relation

that you have described. What was the estimate and who made it?

A. It was made by Mr. Shenehon.

Q. And what was it?

A. It was $5\frac{1}{2}$ per cent.

Q. That would be the effect of the construction of the dam?

A. Yes, sir.

Q. How closely did your observations tally with that computation, if you know?

A. They checked exactly as near as could be determined.

Q. That is they showed the change up to 5 per cent?

A. Yes.

Q. That had been estimated on this method of computation?

A. Yes.

Q. What effect did that change, about which you have just testified, at this dam have upon the increment?

A. The change in the increment from the discharges made last year, cannot be determined. The discharges cover a range of stage of only one-half foot at Ogdensburg.

Q. Having in mind now these observations which you made and your experience, what do you say with reference to the increment of the St. Lawrence River? I am referring to this point at which you made your measurements?

A. It is between twenty-eight and twenty-nine thousand cubic feet for a foot on Lake Ontario.

Q. Does that take into consideration this 5 per cent change about which you have just testified?

A. Yes.

Q. That is to say would the effect of that be to make the increment greater or less?

A. The effect would be to make the increment less.

Q. And you have taken that into consideration in your statement of twenty-eight or twenty-nine thousand?

A. That is my impression of it. I do not remember the exact figures.

Q. That is within how close, do you think, as you have stated it? Is there anything to which you can refer to give an accurate statement?

A. For a stage at Ogdensburg of 245 feet above mean tide, the increment is about 28,000; it is that within one or two per cent.

Q. What measurements if any have you made on the St. Clair River?

A. In November and December of 1908, I made fifteen measurements of the flow of the river on Section Dry Dock, and twenty-two measurements of the flow on a new section, at the head of the river.

Q. What was the purpose of those observations?

A. To determine whether or not there had been any change in the conditions governing the outflow from Lake Huron.

Q. What did you find?

A. The observations on section Dry Dock, which is the old section, showed practically no change.

Q. You measured a new section?

A. Yes, sir.

Q. What was the purpose of that?

A. To furnish a check on the measurements on the old section.

Q. That is to say for the purpose of verifying the computation which had been made with reference to the relation between lake stage and outflow?

A. Yes, sir.

Q. And as a check on the increment as it had been determined by former observations?

A. Yes, sir.

Q. Will you describe a little more in detail the measurements on this new section which you made; tell us a little more in detail just what you did there?

A. The new section which is known as section Gorge, is located about a quarter of a mile from Fort Gratiot Light House, just above the narrowest point in the river. The section is a thousand feet wide.

Q. Is that a comparatively wide or narrow part of the river?

A. It is a comparatively narrow section. The narrowest point is about 800 feet wide. This section is just above it.

Q. Was that a section which was favorable or unfavorable for the purpose of making discharge measurements?

A. I consider the section exceedingly favorable.

Q. Why?

A. The velocity averages between five and six feet per second. The current threads are steady and slightly converging and the velocity is accelerated. Under those conditions, there exists very little boiling or broken current threads; the current threads run very smoothly.

Q. In that connection did you make any measurements with water gauges?

A. During the measurement of the discharge, gauges were maintained at a point about a mile and a half above Fort Gratiot light, and at various points in the river below the section, and a gauge on the section.

Q. How did you make the readings? Describe that. And I assume that what you say as to the readings of the gauge on the St. Clair applies also to the measurements of the Niagara and St. Lawrence?

A. Yes.

Q. How did you make those measurements?

A. The gauge used on the river work is what is known as the small type automatic gauge, designed by the Lake Survey office. It consists of a drum about four inches in diameter driven by a clock. On this drum are needle points every two inches, which engage a roll of paper three inches wide, which passes from a spool on one side over the drum on to a receiving spool on the other side, at the rate of two inches each hour. The elevation of the water surface is recorded as a continuous line on the paper, by means of a float in a box which is attached to a wheel about four inches in diameter, geared to a pencil which moves across the paper. The elevation of a fixed line on the paper is determined by readings of a staff gauge, taken usually once a day. This staff gauge is ordinarily a small box about four inches in square set into the water, in which floats a bottle carrying a graduated staff. The elevation of the top of the box is determined by levels from known bench marks, and the gauge reads distances below the top of the box. These elevations by the staff gauge fix the elevation of a fixed line on the paper, and elevations at any other time are scaled from this line to the stage line.

Q. Where did you say you had these gauges?

A. There was an automatic gauge at Muronia Beach, about a mile and a half above Fort Gratiot Lighthouse; a gauge at the old Ferry slip of the Grand Trunk Railroad, about three-quarters of a mile I think below the section; another gauge at the old Dry Dock of Dunford and Alverson, about three miles below the city; a gauge at Roberts Landing and a gauge at St. Clair Flats ship canal. In addition, during all measurements of the flow, there was a staff gauge read at five minute intervals at Fort Gratiot Lighthouse. There was also an automatic gauge on the section which gave the elevation of the water at that point.

Q. What was the result of these observations which you made at this new section, as to the increment which you determined, as to comparison with the former observations?

A. There are in existence a great many formulae for the flow of the St. Clair River. Comparing the observations on section Gorge with what are probably the best of these formula, the results there in 1908 showed between one and a half and two per cent smaller than indicated by the formulae. Considering the results by themselves, the increment of flow for normal stage of Lake St. Clair is between 20,000 and 21,000 cubic feet per second.

Q. Have you, as a result of this work which you have been doing for the last two, or three years, had occasion to reach a conclusion with reference to the precision of the observations which are made from current meters?

A. Yes, sir.

Q. What do you say on that subject?

A. The velocities as given by the Haskell meter, which we have used in all of our work, are unquestionably true velocities.

Q. Why do you say that?

A. In 1906 on the Detroit River tests were made of the velocity as given by the meters compared with the velocity of the river as given by floats.

Q. Did you have anything to do with those tests?

A. I did.

Q. What did you have to do with them?

A. I recorded all the observations.

Q. So you were on the ground, or the water, all the time?

A. Yes, I recorded the observations.

Q. Describe in detail how you made those tests and what the result of the tests was?

A. Two steel catamarans such as were used in the pontoon sweep, used at one time by the Lake Survey, were suspended in the current of the Detroit River; the upper one fastened to an anchor in the bed of the river and the lower one suspended 200 feet below it by means of two galvanized iron wires. These wires were very carefully measured and were marked at the exact distance of 200 feet. On each catamaran, suspended by an overhang so that the meter ran at least six or seven feet to one side of the hulls, so as to be beyond the influence of the hull, there was suspended a current meter. The floats used consisted of balls of bluing, which were injected into the water by means of a bicycle pump.

Floats of this character, forming part of the water itself, unquestionably give the true velocity of the water. A float was started several feet above the first meter, and as it passed the first meter, both meters were started by one movement. As the float passed the second meter, both meters were stopped. The relation was determined between the velocity of the current as given by the colored balls of water and the mean of the velocities given by the two current meters which had been rated in still water, both before and after the tests. There were seventy-six tests made, and the result showed that the indications of the meters agreed with the velocity of the water by about one-fifth of one per cent.

Q. Have you any other reasons for reaching the conclusion which you have stated with reference to the accuracy of the measurements made by this Haskell current meter?

A. The precision of the measurements themselves has been tested in several cases by the measurement of two sections on the same stream.

Q. Have you had in your own personal experience occasion to do that?

A. Yes, sir.

Q. Where?

A. On the intake canals of the power companies at Niagara Falls.

Q. Tell us what you did there and what the result of that work had to do with your statement as to the accuracy of these current meter measurements?

A. The intake of the Niagara Falls Power Company is between 175 and 190 feet wide, 180 feet at the point of measurement; with a depth of about 12 feet and a velocity of about four feet per second. Two sections were measured on this canal in 1907, one about a hundred feet below the other with slightly decreased width and increased velocities. The two sections showed the same discharge by one-half of one per cent. The intake canal of the Niagara Falls Hydraulic Power & Manufacturing Company is about 120 feet wide and from 16 to 20 feet deep with velocities ranging from one and a half to three feet per second. Two sections were measured in that canal, one from a bridge spanning the canal near the lower end, and one from a cable-way near its upper end. The two sections were separated by over a quarter of a mile. The flow as measured by the two sections agreed by 1.7 per cent. This canal did not offer the best facilities for current meter work on account of dredging work which was going on in the

canal at the time, and the continual passing of a tug back and forth, which broke up the threads to some extent.

Q. How did you compare these two sections, were the measurements taken simultaneously?

A. On the canal of the Niagara Falls Hydraulic Power & Manufacturing Company, simultaneous measurements were made for eight hours. On the canal of the Niagara Falls Power Company, as both sections were determined from cableways, simultaneous measurements could not be made. The check between the sections there is obtained by the indications of a meter run at a point in the head of the canal from a conveyor which carries pulp wood to the paper mill, crossing the canal at its head. This meter was run continuously during all the measurements, and suitable coefficients were derived to give the discharge through the canal in terms of the velocity by this meter. The check between the two sections is the check between these coefficients at a given time. With a given velocity at the meter of the conveyor, the product of the coefficient for Section 1 by the area of the section must equal the product of the coefficient for Section 2, by the area of that section.

Q. Have you done any other work that bears upon the question of the accuracy of these current meter measurements?

A. The measurement of the new section in the St. Clair River indicates the accuracy of the work.

Q. Why?

A. The two sections there are exceedingly different. The lower section is about two thousand feet wide, the upper one only a thousand. The velocity in the lower section is about three feet per second, and in the upper section nearly six. The depth in the lower section lies between twenty and thirty feet; the depth in the upper section reaches sixty-five feet. The sections were measured by different observers at different times, and yet the results agree within less than two per cent.

Q. Do you recall anything else in addition to that about which you have testified, which bears on this matter of the accuracy of those measurements?

A. On the Niagara River, in 1898 to 1900 two sections were also measured. These sections were very different; one was a section from the International Bridge, broken up by the bridge piers, with eddying around the piers to a large extent. The other was an open section half a mile further down, where

the water was running smoothly. The measurements on the two sections agreed by about 1.3 per cent.

Q. What does that indicate to you as an engineer?

A. The tests made in the Detroit River indicate that the Haskell meter gives true velocities, and the agreement of two sections on various streams indicates that the method of measurement, the use of the instruments, gives accurate results.

Q. What do you say as to the accuracy of the soundings? Have you any way of checking soundings on cross sectional areas?

A. The accuracy of the soundings is as great as the accuracy of the measurements of velocity.

Q. Why do you say that?

A. The soundings made by different observers at different times at the International bridge, in spans 3 and 4, under extremely difficult conditions showed absolutely no change in the cross sections. Soundings made on the St. Lawrence River in 1908, at the same points at which soundings were made in 1901, showed absolutely no change in the cross section. Soundings made on Section Dry Dock in the St. Clair River in 1908 checked exactly with the result of earlier work.

Q. What do those facts indicate to you as an engineer?

A. The facts show that the soundings as made are correct to at least within one per cent.

Q. You have given evidence here with reference to the measurement of these velocities and the determination of these increments. What have you to say as to the problem there presented as compared with the problem of measuring earth works for instance, as to whether as a matter of engineering it can be done so as to get any accurate result?

A. I consider the measurement of stream flow, so far as the process is concerned, just as simple and sure as the measurement of earth work. It requires a little more observation, but the process is exceedingly simple.

Q. Did you make any observations with reference to the scour in the St. Clair River?

A. Yes, sir.

Q. When?

A. In the fall of 1908.

Q. And how were those observations made, what was your method?

A. In 1897 and '8, four cross sections were laid out in the rapids at the head of the St. Clair River and established by

monuments at the ends. These sections were sounded in 1898, 1899, 1901, 1904 and 1908. The measurements in 1908 were made by me. The results of those measurements showed that there has been no scouring out of the bottom in that portion of the river to any appreciable extent. There have been minor changes on the four sections, but considering the four sections together, there is no scour shown. On the upper section, the soundings of 1908 show an increase in the depth.

Q. Which section is that?

A. That is the upper of the four sections, established in 1898.

Q. Does that have a name?

A. Section Culvert; it shows an increased depth of about 1.3 feet since 1901. On the second section, section Fish, there is no change in the area shown by the soundings of 1908. On Section Arthur, the third section, since 1901 there appears to be a filling in of about two and a half feet. This is probably due to a wreck which lies just above the section and reduces velocities near the bottom. On section Stauber, which is the fourth section, there is no change shown since 1901; the two areas are identical.

Q. Did you measure the flow in the Erie canal?

A. Yes, sir.

Q. When?

A. 1907.

Q. What was the result of those observations?

A. The flow through the Erie canal at the time of the measurements was about 800 cubic feet per second, between seven hundred and eight hundred cubic feet per second.

Q. As the result of your observations and the study which you have given to this subject, are you able to make any statement with reference to the relation which exists between the level of Lakes Michigan and Huron and the outflow of the water through the St. Clair River?

A. The relation between the flow through the St. Clair River and the elevation of Lakes Michigan and Huron has not changed since the measurements made in 1898.

Q. What do you state the increment to be?

A. For normal conditions of the lakes, the increment is between twenty-three and twenty-four thousand cubic feet per second, for a foot change on Lake Huron.

Q. What do you say with reference to the relation which exists between the elevation of Lake Erie and the outflow through the Niagara River?

A. The flow through the Niagara River with respect to the elevation of Lake Erie is exactly the same as it was in 1899.

Q. And what is the increment?

A. The increment for mean stage is 22,000 cubic feet per second.

Q. That is in round numbers?

A. In round numbers.

Q. If water is diverted from Lakes Michigan and Huron at some other point, what will be the ultimate effect upon the quantity of water which flows out through the St. Clair River?

A. The quantity will be decreased.

Q. Why do you say that?

A. The opening of a second outlet to any body of water is certain to lower the level of that body of water, and the lowering of the level of the lake—

Q. Do you state that as an established, recognized, scientific fact?

A. Yes, sir.

Q. Unquestioned?

A. Unquestioned.

Q. Go ahead?

A. The lowering of the level of the lake means a decrease in the outflow of the river.

Q. From the observations you have made and computations which are based on those observations, what do you say as to the effect of diverting 4,000 cubic feet of water per second from Lake Michigan at Chicago, upon the elevation of Lakes Michigan and Huron?

A. The elevation of Lakes Michigan and Huron would be lowered about two inches.

Q. At one point or all the points?

A. At all the points.

Q. At all the channels and harbors?

A. Yes, sir.

Q. What would be the effect of that diversion upon the level of Lake Erie?

A. Of 4,000 cubic feet diversion?

Q. Yes.

A. The effect would be slightly over two inches.

Q. What would be the effect on Lake Ontario and the St. Lawrence River?

A. The effect would be a little less than two inches on Lake Ontario.

Q. And would the effect of diverting other quantities be in proportion to the figure which you have given for the diversion of 4,000 cubic feet?

A. Yes, sir.

Q. That is if ten thousand were diverted instead of four thousand the lowering would be in the ratio of ten to four?

A. Yes, sir.

Q. And so on for other quantities?

A. Yes, sir.

Q. Did you make any observations, with reference to the water power at Niagara?

A. I measured the amount of water which was being used for power by the Niagara Falls Power Company, and by the Hydraulic Power & Manufacturing Company.

Q. How did you do that?

A. The measurements were made in the intake canals of both companies, in the same manner in which the flow through any stream is measured, as I have explained earlier.

Q. What is the head at Niagara, head of the water?

A. The Niagara Falls Power Company uses about 143 foot head; the head of the Hydraulic Power & Manufacturing Company is about 200 feet.

Q. Translating that into horse power in a cubic foot per second, what is the figure?

Mr. Williams: I object to that. I do not understand the diversion of 4,000 cubic feet a second at Chicago, or any other amount, is going to change the head, or interfere with the operations of these power companies, and if it did, this suit is not brought for the protection of the power companies.

Mr. Wilkerson: Q. Do you understand my question?

A. You want the—

Q. How many horse power in water of that head is there in a cubic foot?

A. The Niagara Falls Power Company generates about 65,000 horse power from about 8,000 cubic feet. That would be about 37,000 horse power for 4,000 cubic feet. The Niagara Falls Hydraulic Power & Manufacturing Company develop a greater amount than that.

Q. Will you check your figures on that, Mr. Moore?

A. About 32,500 for about 4,000 cubic feet.

Recess to 1:30 p. m.

1:30 o'clock, p. m., May 25, 1909.

SHERMAN MOORE, resumed the stand and testified further as follows:

Cross-Examination by Mr. Williams.

Q. Mr. Moore, what would you say as to the possibility of error in the reading of these Haskell Meters, or in the meters themselves?

A. The error of observations with a meter is less than one per cent.

Q. That is the error of observation?

A. That includes the error of rating the meters.

Q. Would there be a possibility of the meter indicating a greater velocity than actually existed?

A. By very small amounts.

Q. What circumstance or situation might cause a meter to indicate a higher velocity than actually existed?

A. The rating of the meter is not absolutely constant but is dependent upon a great many things inherent in the meter itself. Wear on the pivots has some effect; but it has been found that unless some accident accurred to the meter, the difference between two consecutive ratings was ordinarily very small. A single observation might be an error by as much as two per cent; but by the combination of more than one meter, and none of our results are based on one meter only, such errors are largely eliminated.

Q. By taking one meter alone, what situation might cause that one individual meter to indicate a greater velocity than actually existed? Are there any situations that come to your mind readily?

A. The substitution of a new contact pin in the meter will ordinarily for a short time cause the wheel to turn slightly harder, if this occurred at the time of rating the meter it will indicate a greater velocity than actually existed, but the change is very slight.

Q. Does the direction of the current, and the way the current happens to strike the meter have anything to do with it?

A. The meter is so built that the current always strikes the meter square.

Q. So that you would say that the possibility of a meter

recording a greater velocity than actually existed would be very slight?

A. Yes.

Q. What would you say as to the possibility of a meter indicating a less velocity than actually existed?

A. A meter would be just as likely to indicate a less velocity as a greater velocity.

Q. Not any more likely?

A. No more likely.

Q. Are there any situations that you can think of that would cause such a result?

A. The pivot on which the wheel spins is occasionally sharpened, and after the pivot is sharpened, it takes a few days for the pivot to wear smooth. During that period there would be a very slight variation.

Q. If there should be a temporary interference by a small amount of weeds or string or anything of that kind that would wrap around the pivot, would that have any effect temporarily?

A. If such a thing occurred, it would. The meters, however, are inspected so frequently that any condition of that kind could not exist for more than an observation at a single point.

Q. An interference of that kind lasting only a very short time would indicate a less velocity than actually existed, wouldn't it?

A. Yes.

Q. Would cause the indication of less velocity?

A. Yes.

Q. Is there any way you can guard against those things occurring except by frequent inspection?

A. The meter wheel is so built that it is designed to throw off anything of that kind and in my experience, with one exception I think, I have never found anything of the kind on the meter. In the canal of the Niagara Falls Power Company, late in the fall, there was an enormous mass of dead vegetation floating in the water, and at times that would wrap around the meter. I have never seen it anywhere else.

Q. Did you testify as to the effect in the St. Lawrence River of the diversion of water at Chicago?

A. Of the effect in the river? No, sir.

Q. The St. Lawrence River?

A. No, sir.

Q. How frequently did you find the effect of these weeds in the power canal?

A. It was only on two or three days which followed severe storms.

Q. Well, how frequently did you find the weeds interfering with the efficiency of the meter?

A. The weeds were removed from the meter about once every thirty minutes.

Q. And how many times?

A. During these—I think there were three days.

Q. Every thirty minutes for three days?

A. Yes.

Re-direct Examination by Mr. Wilkerson.

Q. I think you said you never had any experience with weeds except at the one place?

A. Yes.

Q. That was on the Niagara River?

A. Yes.

Q. Was there a bed of weeds in the river above where you made the observations?

A. Yes, sir.

Q. Very thick?

A. Yes, sir, very thick.

Q. And the effect of the storm was to loosen those?

A. Yes.

Q. What did you do with those observations, when you found the weeds?

A. They were all rejected.

Q. You didn't take those into consideration at all?

A. No.

Q. And they do not enter into this result about which you testified?

A. No.

Q. You did not have any trouble with weeds in connection with any of these other observations about which you testified?

A. No, sir.

Q. In either the St. Clair River or any other place concerning which you testified?

A. No, sir.

Q. Take the measurements in the St. Clair for instance,

was there anything present there which interfered with the operation of this meter, weeds?

A. There were no weeds there whatsoever. At times after a storm, when a meter occupied a position close to the bottom of the river, there was a little sand.

Q. Could you detect that situation?

A. Yes.

Q. What did you do with those observations?

A. Those observations where it was known that it occurred were rejected.

Q. What about your detecting them in that situation, did you watch for it closely?

A. Yes, it was watched for closely and the meter was examined each time after it had been to the bottom, and thoroughly cleaned so that the condition was remedied.

Re-cross Examination by Mr. Williams.

Q. What would be the effect upon the accuracy of your measurements of the passing of boats in the channel?

A. I have been unable to detect any effect in the observations.

Q. Is it your opinion then that the passing of boats at the time you were making your observations would not affect the accuracy of those measurements?

A. I do not think that the passing of boats did affect the accuracy of any of the measurements.

Q. There were boats passing through the channel during the time that you were making your measurements, were there not?

A. There were a few.

Q. When was it that you made these measurements in the St. Clair River?

A. Last November and December.

Q. How many days were occupied in making those measurements?

A. The measurements of the discharge of the river were made on nineteen days on the upper section.

Q. How many days were occupied on the other section?

A. Measurements were made on eight different days.

Q. Will you give us the dates on which you made the observations on the upper section?

A. On November 18, 27, 28, December 1, 2, 4, 9, 10, 11, 12, 15, 16, 17 and 19.

Q. What were the dates of your observations on the other sections?

A. November 7, 9, 10, 11, 21, 23, December 14 and 18.

Further Re-direct Examination by Mr. Wilkerson.

Q. Counsel asked you about passing boats. Were there many passing boats at the time you made these observations?

A. There were very few passing boats.

Q. Why?

A. Both on account of the lateness of the season and the unfavorable year for vessel commerce.

Q. I am not quite sure that I understood your answer as to the effect of a new pin on this meter.

A. The construction of the meter is such that each revolution of the wheel makes and breaks an electric circuit which operates a counting register at the surface. The contact is made on the back end of the wheel. There is a disc, half of it is hard rubber and half of it is silver, and bearing on this disc with a very slight pressure is a small silver headed pin which is insulated from the body of the meter. The pins wear out, and it is necessary occasionally to replace them. When a pin is replaced, it is ordinarily slightly longer than the old one which was removed, although an attempt is made to get the pressure as nearly uniform as possible. Any change from that cause is very slight, however.

Q. If the pin presses a little harder does it make the meter indicate a greater or less velocity?

A. It makes the meter indicate a greater velocity. I am mistaken; it would indicate a less velocity.

Q. Maybe I can clear that up. Does it make any difference in the result whether the pin is changed when you are rating the meter or when you are making these measurements?

A. When the pin is changed the pin is ordinarily changed during the rating, so that the rating is made under the new conditions. Occasionally it is necessary to change the pin during the measurements.

Q. Is there any difference in the result when the change is made in the rating or in the making of the observation; if so what?

A. When the change is made at the time of the rating,

the velocities are too large as the new condition is embodied in the rating.

Q. How often do you rate the meter?

A. Meters are ordinarily rated about—well the time varies. On the Niagara River work, the meters were rated about once a month. On the St. Clair River work, the meters were rated before beginning the work and after the work was completed.

Q. How many meters did you use?

A. We used four meters.

Q. In both pieces of work?

A. On the St. Clair River, and three meters on the Niagara River at one time.

Q. Did you make any tests from day to day which would indicate the rating of the meter?

A. On the Niagara River, at least once a week the meters were run side by side in the channel, and simultaneous observations obtained, which showed any change in the rating of any meter.

Q. That is there was a check?

A. Yes.

Q. A check among the meters?

A. Yes. On the St. Clair River every measurement of a vertical curve gave a check on the rating of the two meters employed, by observations when running at four-tenths depths side by side.

Q. Did you make any spinning tests, spinning the meter out of the water?

A. Once a day it was customary to spin the meters in the air and record the number of seconds they would run. The test is ordinarily made in the morning after the meters were cleaned, the first thing in the morning.

Q. Let me put this question to you: just tell us all the precautions you took to see that the meters remained in condition?

A. I didn't catch your question.

Q. You started out to state with reference to one precaution that you took to see that the meters remained in good condition. Go ahead with that and state any other precaution that you took to check up on these meters and see that they remained in condition?

A. The meters were always handled with extreme care. They were cleaned and oiled by one of two men; that is the cleaning was confined to two men, so that it was as nearly uni-

form as possible. Spinning tests in the morning indicated any abnormal condition in the meter. Current meter tests weekly on the Niagara River, and five and six times a day on the St. Clair River, showed up any temporary abnormal condition in the meter. And the meters were very carefully examined each night for any unusual condition in wear on the sides of the body, or anything which would interfere in their holding the rating. They were watched as carefully as it was possible to watch them.

Mr. Wilkerson: That is all.

F. G. RAY, a witness called on behalf of the Government having been duly cautioned and sworn, testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your name?

A. F. G. Ray.

Q. Where do you live?

A. Detroit.

Q. What is your occupation?

A. Civil engineer.

Q. How long have you been engaged in that occupation?

A. I graduated from the State University of Iowa in 1892; and I have been engaged in civil engineering work since then.

Q. In a general way, what work have you done since 1892?

A. I was engaged with the Mississippi River Commission, from the fall of 1892 until 1900. Since then I have been engaged with the Lake Survey.

Q. What has been the scope of your work on the Lake Survey?

A. I have had charge of field parties on triangulation, hydrography and topography during the summer seasons; and have been employed on reduction of notes, water levels, hydraulics, etc., in the winter.

Q. Have you done any work in connection with the determination of what you call critical areas on the lakes?

A. Our field work has been principally an examination of critical areas.

Q. What do you mean by critical areas?

A. Areas that show depths that are or are suspected to be dangerous to navigation; and investigation of channels where the navigable depths are narrow and close.

Q. What particular critical areas have you investigated? Start in with the lower end of Lake Michigan, for instance, and come around?

A. Last season I made a survey of the south end of Lake Michigan, extending from the vicinity of Gary to the mouth of the Chicago River.

Q. What was the nature of that work, what were you trying to find out?

A. It was principally sounding and sweeping for shoals, wrecks and other obstructions to navigation.

Q. Did you find any shallow places down there?

A. We found a number of shoals in the vicinity of Indiana Harbor, that were not charted correctly.

Q. What did you find? State specifically the facts that you found with reference to those shoals?

A. You mean the nature of the shoals?

Q. Yes, and how deep the water was; what limitation, if any, they imposed on the draft of vessels. You are referring, to refresh your recollection, to some chart or map?

A. This is a chart of the last season's work.

Q. That you caused to be prepared?

A. That I caused to be prepared.

Q. Refer to that now, refresh your recollection and just give us the facts with reference to those shoals?

A. There is a series of irregular sand shoals, hard sand bottom, lying off in a northeasterly direction from Indiana Harbor, extending out some five or six miles, in which the prevailing depths are from 16 to 18 feet.

Q. Of what extent are those depths of 16 to 18 feet, for how much of the lake?

A. The area of shallow water is very irregular. There are several parallel reefs that are from one to two miles long, extending about north by west and south by east in direction. There is deep water between them. These shoals start near the shore and extend, as I said before, out about five or six miles, and practically block the entrance to Indiana Harbor.

Q. Vessel men going to Gary or Indiana Harbor have to take what course?

A. Vessels bound for Gary still come by the way of South Chicago. There are no aids to navigation yet at the Gary harbor. They come to South Chicago, pick up the light station there and go due east about seven miles and then south into the harbor, in a roundabout course to escape these shoals.

Q. Do these conditions you describe here have anything to do with that?

A. Yes.

Q. What?

A. There is no navigable depth across these shoals. They are obliged to go around, with the present draft of boats.

Q. What other critical areas do you know anything about?

A. I might enumerate practically all of the harbors on Lake Michigan, though I have had nothing to do with some of them.

Q. I am speaking of your own observation. Go ahead, what is the fact with reference to the harbors of Lake Michigan, let us have in detail the facts about them?

A. Most of the harbors that I have had anything to do with are dredged to practically the present limits of navigation. Occasionally a boat goes in there with a specially low stage—

Q. When you speak of the present limits of navigation, what do you mean by that?

A. The present draft of the boats, that is, of the heavier laden boats.

Q. Well, now, take some of the harbors about which you know particularly?

A. The Milwaukee harbor, Racine.

Q. Tell us the facts about Milwaukee?

A. There are times when boats are obliged to wait for a rise in the stage to get across certain places that have shoaled to less depths than the general depth of the channel.

Q. That is to say, is Milwaukee harbor a harbor in which the depth of the water has anything to do with the size of boats that can come in?

A. All of the dredged harbors are affected by low stages of water.

Q. What other harbors are subject to that effect?

A. Racine Harbor and Green Bay, Sturgeon Bay canal. I suppose all of the harbors on the east shore. I am not familiar with them.

Q. I am asking you of the difficulties about which you know?

A. Cheboygan Harbor, Bay City.

Q. Do you know anything about the shoals in the straits off Cheboygan?

A. I made a survey of the shoals in the straits north and east of Cheboygan a year ago last summer.

Q. What is the fact about those, what did you find?

A. There are several shoals in that vicinity in which there are depths of 19 to 22 feet.

Q. Over what area?

A. They are small areas, several shoals.

Q. Does that have any effect upon the sailing course of vessels, if so, what?

A. The Lake Survey found it necessary to change the sailing courses on the Straits chart about a mile to the northward.

Q. Why?

A. To escape these shoals.

Q. Go on around, what other critical areas do you have knowledge of?

A. Alpena.

Q. What is the fact about that?

A. That is a dredged channel which is limited by the depth of dredging. The south end of Lake Huron is also shoal.

Q. Covering what area?

A. The channel from the head of St. Clair River for perhaps two or three miles northward.

Q. What harbors does that affect?

A. It is the south end of Lake Huron.

Q. Does that affect navigation to any points?

A. The entire navigation down the Detroit River passes through that channel. With a south wind, the boats drag the bottom there continually. The channel through the St. Clair—

Q. Is the navigation there limited by the depth of the water?

A. The navigation there is limited by the depth of the water at the present time.

Q. How deep is the water?

A. It is about 19 to 20 feet; depending considerably on the direction of the wind.

Q. What other critical areas have you investigated?

A. The channel through Lake St. Clair.

Q. What is the fact about that?

A. That is very little deeper than the present draft. There have been complaints of boats striking the bottom.

Q. Did you see anything of vessels dragging through the St. Clair?

A. I have followed boats through there when they stirred up the mud and sand from the bottom with their propellors.

Q. How many times?

A. I have a recollection of seeing that two or three times.

Q. Have you covered now the critical areas that you have investigated?

A. There is a large area at the west end of Lake Erie that is limited by the stage of water.

Q. How large?

A. Several miles from the mouth of the Detroit River out to deep water.

Q. What navigation does that affect?

A. Affects all the commerce on Lake Erie, commerce from upper ports.

Q. How deep is the water there?

A. It varies according to the stage of Lake Erie and the direction of the wind.

Q. Between what limits?

A. It would be between 19 and 21 feet.

Q. Over how extensive an area does that condition in the west end of Lake Erie affect navigation?

A. I am not prepared to say as to how large the area is.

Q. How many miles would you say? Vessels say coming down the river bound for Buffalo, how many miles—

A. Some three or four miles from the mouth of the river covers.

Q. That is, there is a space of three or four miles where that condition would affect the vessels?

A. From the mouth of the river.

Q. Have you investigated any other critical areas?

A. I should call the entrance to Green Bay through the Poverty Island passage a critical area.

Q. What do you know about that?

A. There is a varying depth of about 22 feet.

Q. Over what area?

A. It is just a short distance, perhaps a quarter to a half a mile.

Q. Is there any other critical area of which you have knowledge?

A. There is what might be called a critical area north of Thunder Bay Island.

Q. What is the fact about that?

A. There is quite an extensive area there with a prevailing depth of 26 feet and a minimum depth of 25.

Q. You say, "quite extensive." Can you define the limits a little more accurately?

A. The limits, within the five fathom curve is probably about sixteen to eighteen square miles.

Q. Vessels bound to what ports are affected by that condition there?

A. Practically all of the traffic from Lake Superior or Lake Michigan to Lake Erie passes over this area.

Q. You have had to do in your work with the Lake Survey with water gauge readings, have you?

A. I have had considerable to do with the reduction of the records.

Q. Have you had anything to do with the readings themselves?

A. I have inspected the gauges occasionally, and instructed the gauge tenders.

Q. I wish you would somewhat in detail describe these water gauges and tell us how the readings are made, and what part they play in these measurements?

A. The gauge that we use for our regular stations is an automatic self-registering gauge designed by Mr. Haskell, in which the stage of the water is shown on a continuous hydrograph. The gauge is run by clock work. The record is made on a continuous roll, generally for about a month's duration for each roll. The time is marked hourly by a separate device, and a stationary pencil on this gauge marks the datum plane. The records are derived from scaling between the datum plane and the stage line. The value of the datum is derived by a series of staff gauge readings and the scalings from the roll at the time the staff gauge readings are taken give the value of the datum plane. These staff gauges are referred to our standard bench marks. In reducing the records for purposes of getting daily and monthly means, we scale hourly readings, hourly ordinates. The mean of the twenty-four hourly ordinates constitutes the daily mean, and the mean of the daily means for the month gives the monthly mean.

Q. What do you know about the accuracy of these readings?

A. In what respect?

Q. Is there any checking up on that or verifying it?

A. A test of accuracy comes through a comparison of different gauges on the same lake or connnected lakes.

Q. What do you know about that now? Are you able to make any statements as to the accuracy of those readings?

A. We have gauges on Lakes Michigan and Huron which give a comparison in monthly means each month, and these

checked always, practically always, within a few hundredths of a foot.

Q. Between each other?

A. Between each other; sometimes there is a variation due to prevailing winds, but you can bank on the average.

Q. What does that agreement indicate with reference to the accuracy of the observations?

A. It indicates that any movement on one part of the lake is felt over the entire area of the lake.

In making our level adjustment for establishing datum, the water levels were used in connection with the precise levels, and were given the same weight as the line of precise instrumental levels.

Q. I think you said you had something to do with the computations determining the relation that exists between the stage of the lake and the outflow through the rivers?

A. Yes.

Q. What have you had to do as to those computations?

A. I have made up some of the computations, checked others, and have always studied the readings that have been sent in by the several assistants; am familiar with their work.

Q. You are familiar with the process used, are you?

A. Yes, sir.

Q. And with your practical work, and your knowledge of the subject as a basis, are you able to make any statement as to the relation that exists between the stages of Lakes Michigan and Huron and the outflow through the St. Clair River; if so, what is the fact?

A. I made a computation from the observations that were taken by other parties, and I derived an increment of outflow which is between twenty-one and twenty-two thousand cubic feet per second.

Q. What do you mean by increment of outflow?

A. Difference in outflow for a change of one foot stage on Lakes Michigan and Huron.

Q. Do you know anything about the relation that exists between the levels of Lakes Huron and Michigan and Erie, and Lake St. Clair?

A. The effect of a varying stage of Lake Erie on Lake St. Clair is about 44 per cent., and of Huron on Lake St. Clair about 37 per cent.

Q. What is the effect of the lowering of those lakes upon St. Clair?

A. They would have the same effect; the lowering of Lake

Huron would lower Lake St. Clair about 37 per cent. Lowering of Lake Erie would lower Lake St. Clair about 44 per cent. Those percentages are derived from the past gauge records that we have.

Q. You have gone all through those computations?

A. Yes, sir.

Q. You have had to do with them. You are speaking of work you have done yourself?

A. I have done that myself, yes, sir.

Q. If Lakes Michigan and Huron were lowered two inches, and Lake Erie two and a half inches, what would be the effect upon the level of Lake St. Clair?

A. It would be about an inch and three-quarters on Lake St. Clair.

Q. How do you determine that?

A. The effect on Lake St. Clair from the lowering of Lake Huron is about 37 per cent. I would give about three-quarters of an inch as the effect from the lowering on Lake Huron, and the lowering from Lake Erie would be about 44 per cent., of two and a half inches, or a trifle over one inch.

Q. You and the two together?

A. Add the two together.

Q. Which gives the total effect?

A. Total effect; would be an inch and three-fourths practically.

Q. You have come in contact, have you, Mr. Ray, with matters relating to navigation, in your connection with the Lake Survey?

A. Matters relating to what?

Q. Relating to navigation; that is to say, have you come in contact with matters relating to navigation to such an extent that you have any knowledge as to the effect of a lowering of two or three inches in the critical areas about which you have testified upon navigation?

A. I think I have.

Q. What would be that effect?

A. The effect of a lowering of two or three inches would be to lessen the draft of vessels by that much.

Q. Where would it have a practical effect?

A. It would have a practical effect on the load of vessels for passage through the critical rivers or into shoal harbors.

Q. Over the critical points and the critical areas about which you testified?

A. Yes.

Cross-Examination by Mr. Williams.

Q. In your opinion, Mr. Ray, would it be advisable to now proceed to deepen the lake at these critical points which you have testified about?

A. I did not catch the first part of your question.

Q. (The question was read to the witness.) In the interests of navigation?

A. I think it would be impracticable in some cases.

Q. Would it be necessary in order to serve the interests of navigation?

A. Any lowering of the waters of the lake would decrease the allowable draft of boats.

Q. You do not catch the purport of my question. I ask you whether or not in your judgment it would be in the interests of navigation to now proceed to dredge out and deepen the lake at these critical points that you have testified about?

A. It would be to the advantage of navigation to have some of these places dredged.

Q. Just indicate one of those places that you think it would be in the interests of navigation to dredge?

A. Lime Kiln Crossing.

Q. What is the depth of the water now at the Lime Kiln Crossing?

A. It varies with the stage. I think the limit now is about 21 feet.

Q. And in your opinion to what extent should that be deepened at that point?

A. I am not prepared to say as regards to that.

Q. Do you think it would be necessary to deepen it any? Would it be in the interest of navigation?

A. It would always be in the interest of navigation to have deeper channels.

Q. We are speaking now of this particular point, Lime Kiln Crossing.

A. (No response.)

Q. Are you familiar with the expense of deepening channels?

A. I am not.

Q. These critical areas that you have testified about, where the depth of water is from 23 to 25 feet, under what circumstances are those areas incapable of accommodating navigation, any navigation now taking place on the Great Lakes?

A. Vessels loaded to 20 feet would strike bottom and dam-

age themselves in considerably deeper water in a heavy sea; or during extreme low stages caused by prevailing winds. The rolling of the boat and the dragging down of the boat under headway also give a deeper draft.

Q. How many feet would you say that that rolling effect would be noticeable, or the diving effect.

A. I would not consider anything less than 30 feet would be safe depth, in a heavy sea.

Q. For a 20-foot draft vessel?

A. For the deep laden boats.

Q. That is if a vessel was loaded to a depth of 20 feet, you would consider it necessary to have a depth of 30 feet in order to protect that vessel in case of heavy sea?

A. That, of course, gives some margin of safety.

Q. Well, how much of a margin of safety is there in that ten feet?

A. I believe that a boat loaded to 20 feet would touch on 28 feet of water (mean stage) under the most adverse circumstances.

Q. How is that?

A. A boat would touch on something in the neighborhood of 28 feet, so they have reported.

Q. Then there would be, in your opinion, a margin of about two feet by providing for a 30 foot depth, a margin of safety of at least two feet and no more?

A. I don't think that is measurable precisely.

Q. In your opinion. You cannot testify to an accurate mathematical certainty, on a proposition of that kind, I assume?

A. I would not care to.

Re-direct Examination by Mr. Wilkerson.

Q. Coming back to those shoals again, and the relation of shallow water there to practical navigation of the lakes, is there any kind of weather which might have some effect on navigation, even though there were a channel around, if they went into South Chicago and went around that way?

A. It is very often the practice of masters to hug the lee shore to protect themselves from the heavy seas out in the open lake, and some of these critical areas are along the shores.

Q. You cannot always follow the channel around the shoals in thick weather, can you?

A. You cannot.

Q. Do you know anything about the improvements which are proposed and under way, which will make these critical points about which you have testified more important with reference to navigation?

A. I suppose the construction of the Livingston channel and the new lock at the Sault will have an effect of deepening the draft of boats.

Q. What would be the relation of that situation to these critical areas about which you have testified?

A. That will make depths of between 20 and 30 feet more critical than for shoaler draft boats.

Mr. Wilkerson: That is all.

Recess to May 26, 1909, at the hour of 9:30 o'clock a. m.

F. C. SHENEHON, a witness called on behalf of the Government, was first duly cautioned and sworn and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your name?

A. F. C. Shenehon.

Q. Where do you live?

A. Detroit.

Q. What is your occupation?

A. Civil engineer.

Q. What position do you hold at present?

A. I am principal civilian engineer of the United States Lake Survey.

Q. Stationed where?

A. At Detroit.

Q. What has been your education as an engineer, college education?

A. I attended the University of Minnesota, and hold two degrees, Bachelor of Civil Engineering and Civil Engineer.

Q. What has been the nature of your work since you commenced the active practice of your profession?

A. I was on railroad location and construction between 1886 and 1888. In 1888, I opened an office at Sault Ste. Marie and was in general practice as a civil engineer; and in 1891 I entered the service of the Engineer Department of the Government in the construction of the Poe lock at Sault Ste.

Marie. I was at Sault Ste. Marie engaged on work connected with the building of the lock and the channellization of St. Mary's River up to 1898. The work there included also discharge measurements, on St. Mary's River made in 1896, and reduction of measurements and discussion of hydraulic measurements at that time.

Q. What next?

A. In 1898, July, 1898, I was transferred to Buffalo as engineer for the Board of Engineers on Deep Waterways, in the discharge measurements of the Niagara River; and for two months had charge of the office in that work. That included slope measurements on the river, and discharge measurements at the International Bridge. The Lake Survey then took up the work, and I had charge of the office at Buffalo up to August, 1900. During that period we were engaged in making discharge measurements and the reduction of the same. In August of 1898, I was transferred to the St. Lawrence, and made discharge measurements of the St. Lawrence River during the fall of 1900 and the spring of 1901. Then I was engaged on surveys, a resurvey of the St. Lawrence River for the balance of that year.

I should have stated that during the winter of 1901, I made discharge measurements of the upper St. Lawrence River through the ice, in corroboration of the measurements at Point Three Points. During 1902 I was engaged in surveys on the St. Lawrence River. In 1903, 1904 and 1905 I was in charge of surveys on the lakes, mainly Lake Erie, using the steamer General Williams. In connection with that work, I was afloat making surveys, and became acquainted with lake conditions. In 1906, I was engaged in work on the Niagara River in connection with the Preservation of Niagara Falls, hydraulic work; and during that season I was ordered to the Detroit office to relieve Mr. E. E. Haskell, Principal Assistant Engineer of the Lake Survey, Mr. Haskell going to Cornell University as Dean of the School of Civil Engineering. Since that time I have acted as principal Civilian Engineer of the Lake Survey.

Q. You have spoken, as part of your work and experience, of having had to do with the making of discharge measurements. What do you mean by that? What is the purpose of such measurements? You referred to the Niagara River, the St. Lawrence and the St. Clair River in that connection?

A. The object of the discharge measurements is to establish a relation between the elevation of the lake surface and

the river outflow. That is, for a particular elevation of the lake surface in the vicinity of the head of the Niagara River, for instance, there is a certain volume of outflow, perhaps 200,000 cubic feet per second. Now, when the lake rises a foot, the outflow is increased for two reasons, namely: because the water is deeper in the river, and because also it is flowing with a somewhat higher velocity. And when the lake at the head of Niagara River has gone up a foot, the discharge might be 222,000 cubic feet per second instead of the 200,000 cubic feet at the foot lower level. A long series of observations, or a series of observations in which the stage of the lake is at different elevations, allows us to state a relation between the elevation of the lake surface and the quantity of water flowing out of the river.

Q. You have given some consideration, have you not, Mr. Shenehon, to the question which is presented in this case, namely, the extent of the lowering of the Great Lakes system due to a diversion of the water from the lake at Chicago?

A. I have given very considerable attention to it.

Q. You have gone over the questions that are involved, and have made a special study of them, have you not?

A. Yes.

Q. With a view to reaching a conclusion on that subject?

A. Yes.

Q. Now let me put rather a general question to you first, before we go into those matters that relate to the determination of the exact extent of the lowering. As a result of your observations and study, which you have given to these questions, what have you to say as to the effect of the diversion of the water from Lake Michigan at Chicago upon the elevation of Lakes Huron and Michigan; and state your reasons for it?

A. It is certain to be followed by a lowering of Lakes Michigan and Huron.

Q. Why do you say that, independent of any obesrvations or computation as to the extent of the lowering; I mean the general principles that apply there that lead you to make that as an absolute statement?

A. The level of the lake is determined by the amount of water presented for discharge in its outlets, and the natural outlet (in the case of Lakes Michigan and Huron, the St. Clair River), at a given lake elevation, can do a certain amount of work in disposing of that surplus water. Now, if the work of the St. Clair River is assisted by an independent, or a new canal, as at Chicago, the amount of water to be disposed of by

the St. Clair River is lessened, and the lake will drop to a point where the sum total of the outflow in the St. Clair River and the drainage canal equals what it would be in the St. Clair River, at a higher lake elevation under the earlier conditions.

Q. A moment ago you made some reference to velocity, in connection with the depth of the lake. Will you state again and a little more in detail just what that relation is. I think you said the more water there was in the lake, the higher the lake was, the faster the water would flow?

A. It is flowing under a higher head.

Q. Is that the result of the application of natural laws?

A. It is a general principle that the speed of water bears some relation to its head, other things being equal.

Q. Now you have spoken of the lowering of the lakes as the result of the diversion of water at Chicago. With what meaning do you use the word "lowering"?

A. Lowering is referred to the lake surface which would have prevailed in the absence of the diversion; that is, the lake may actually rise, while this lowering is going on at the same time, in just the same way that a man who is on a railroad train traveling *east* may reach the tail end of the car he is in by walking *westward.* It is a case of two movements going on at the same time. This lowering is going on, and it is independent of the other fluctuations that may prevail at the same time.

Q. What is the relation between the lowering caused by the diversion of this water at Chicago and the outflow in the St Clair River?

A. I do not know that I understand the question.

Q. (The question was read to the witness.)

A. The level of Lakes Michigan and Huron would fall until the lake at a lessor stage is discharging in the two outlets what is discharged in the St. Clair River alone under the normal condition of lake level.

Q. In connection with the waters of the Great Lakes, you make use of the term "net supply." With what meaning is that term used?

A. Over a long term of years it is the amount of water discharged from the lake through its outlet.

Q. Now what are the elements that enter into the determination of this net supply?

A. In the case of Lakes Michigan and Huron, the water brought in by the St. Mary's River, and the rainfall upon the lake's surface itself, the rainfall upon its drainage area or

water shed, less the evaporation which takes place from the water surface and from this water shed.

Q. You speak of evaporation, rainfall, etc., as being elements in determining the quantity of water there is in the lakes to be disposed of. Those are variable elements, I assume; that is, they change from time to time?

A. Yes.

Q. Now what relation exists between those and this element of the diversion of the water at Chicago?

A. Why, the diversion is independent of it. It makes no change in these elements, evaporation, rainfall.

Q. That is to say that remains a fixed factor?

A. Yes.

Q. Which modifies what would be the resultant of the others, whatever that might be?

A. Yes.

Q. I think you have already stated that you have made considerable study and have done considerable work in investigating the outflow through the St. Clair River, did you, Mr. Shenehon?

A. I have done some work in investigating the St. Clair River.

Q. And in connection with the matter that we now have under consideration here, you caused to be made certain plates showing the result of the observations, did you?

A. Yes.

Q. Now I wish you would take up those plates. They have already been marked here for identification as "Complainant's Exhibits 1, 2, 3 and 4," respectively. Starting in with No. 1, will you state what the purpose of preparing that was, how it was prepared and what you had to do with the platting of those observations; what you know with reference to the correctness of the platting, and what the conclusion reached from the observations which are there platted is, with reference to the relation between the elevation of the lake and the discharge of the St. Clair River?

A. On this plat, the elevations of Lake Huron at Harbor Beach are platted in the vertical.

Q. These observations with reference to the stage of the lake were made from the records here in the office?

A. From the records of the United States Lake Survey.

Q. And the others, the observations as to the outflow, where did you get those figures?

A. From the measurements of the St. Clair River as derived from the records of the United States Lake Survey.

Q. Are those records here in Detroit, are they kept here?

A. Yes.

Q. In permanent form?

A. Yes.

Q. You have the names of the men who made the observations in each case, have you?

A. Yes.

Q. And that is a matter of record here?

A. Yes.

Q. What do you know as to whether or not the observations both as to lake elevation and as to the outflow through the river were correctly put down on the plate?

A. I have checked the platting of that, and know that they are correctly platted.

Q. The platting then is a correct representation of those observations as they appear from the records of the Lake Survey?

A. Yes.

Mr. Wilkerson: Are you gentlemen ready at this time to decide this question: whether this plat may be considered precisely as if the witnesses who made the observations were produced and testified; that these observations were made in the way in which it has already been testified in the case as to observations with reference to the determination of the stage of the lake and the outflow; and that if each one of the witnesses who had to do with the making of these observations were put on the stand, he would testify that he made the particular observation, and that it is correctly put down in the records of the office. What I desire to obviate is the necessity of producing what you would call the best evidence with reference to the observations, and to give to the records of the Lake Survey the same effect that would be given to the testimony of the witness, if he was on the stand and said that he made that observation.

Mr. Williams: We will accept the records of field work, as filed and reduced in this department, as being competent evidence, subject to an inquiry as to the probable limits of error of the original observations.

Mr. Wilkerson: Subject to the right on your part to inquire into probable error of individual observations.

Mr. Williams: Yes. Of course, I would say this, I do not know that we are prepared to admit the correctness of all the

methods of reduction. In using the word reduction of observations, I mean to include simply the determination of the actual elevation of a station, for instance, or the determination of the quantity of discharge in an individual observation. We would not want to admit the correctness of these methods in themselves. We will admit the correctness of the data on which they are based.

Mr. Wilkerson: That is the point. The agreement is that the records of the Lake Survey may be treated as of the same effect as the testimony of the witnesses who made the observations; and it is not necessary to produce, and introduce in the record in this case all of those records, but that the witness may say they are correctly represented on the chart. You have then, of course, the right if you want to, to take those observations and to recheck them to see whether or not they have been in fact correctly platted.

Mr. Williams: They would be as open to us as though the man was testifying.

Mr. Wilkerson: Yes. Now, we have Mr. Shenehon's statement that they are correctly put down. You have the unquestioned right to check that if you wish and to show that the platting is inaccurate in any respect, or that you reach different results from the ones he has reached. In other words we get the observations as the foundation.

Mr. Williams: Yes, the original data we accept.

Mr. Wilkerson: Each side can go ahead with its own method.

Q. Starting out now with the foundation that you have on this plat "Complainant's Exhibit No. 1" a correct graphic representation of the observations as they appear from the records of the Lake Survey, will you now go ahead with your description of the plat?

A. The elevation of Lake Huron at Harbor Beach is platted for a discharge observation in the vertical, and the volume of river flow is platted in the horizontal scale, increasing from the left hand towards the right. Using these two scales as a system of rectangular coordinates, an observation which here consists of a group of ten actual discharge observations, except as specifically stated on the plate itself, is platted in the vertical at its proper elevation of Lake Huron, and in the horizontal with the corresponding volume of outflow in cubic feet per second. After the observations thus grouped are platted, a straight line is drawn threading these observations, and this straight line is taken to indicate the

relation between lake elevation and volume of outflow. The exceptions to the groups having ten observations in each are: U has four, Y six, Z eight and Alpha seven. The total number of discharge measurements is indicated at 255. A note appears on this plate that observations of 1901 were adjusted for abnormal stage of Lake St. Clair. Those observations were not taken into account in drawing the line or deriving the increment. They are platted simply to show where they do fall when adjusted for the abnormal stage of Lake St. Clair.

Q. Why were those disregarded, Mr. Shenehon?

A. During the winter and spring of 1901, St. Clair River was blocked with ice, and Lake St. Clair showed an abnormally low stage.

Q. Was that an extremely extraordinary condition, the one that was prevalent that year?

A. Yes. I do not know another instance where Lake St. Clair was as low and held as low in its relation to Lake Huron, as that particular spring.

Q. Was the discrepancy a wide one?

A. They were rejected and treated in this way, because they do not represent normal conditions between Lake Huron and Lake St. Clair. The attempt to get the law of discharge is to get it for normal conditions and the use of these observations of 1901 would have falsified, rather than made the truth clearer.

Q. Having drawn that line representing the law of discharge, you derived what we refer to in this matter as the increment. How do you determine that after you plat the observations?

A. This diagonal line passes between two horizontal lines a foot apart in lake elevation, as between 580 and 581, and dropping a vertical line from the point of intersection with the upper horizontal until it intersects the lower, the base of the triangle formed is the increment. An increment simply means the rate of change of outflow for a change of a foot in elevation in lake surface. That description is perhaps rather involved, because the increment is an exceedingly simple thing. It bears the same relation in a discussion of this kind that interest does in financial discussions. It is the rate. It is the rate of change of outflow for a foot change in the lake level. If we had taken two observations, one of them being at 581 and another one at 580, and these observations

were absolutely correct, the difference between those would be the increment.

Q. The increment as derived from those particular observations is correctly stated on that plat is it?

A. Within such limits as I will state later in my evidence.

Q. Now I understand that the data relating to those observations have been placed in the hands of counsel on the other side?

A. Yes.

Q. For the purpose of going over them and making any question they desire with reference to the accuracy of the plat as shown?

A. Yes.

Mr. Wilkerson: It is understood that we need not put those figures in the record, is it not, Mr. Williams, unless you wish to have them in by reason of something which you may wish to question as to the accuracy of the plat as drawn?

Mr. Williams: I think we would like to have this material here bearing upon the summary of discharges of the Niagara River and of the St. Clair River, testified to as being correct transcripts from the original field data.

Mr. Wilkerson: Q. With reference to these original observations, just what data have you furnished the counsel on the other side, so that we may have it here in the record?

A. For the St. Clair River, tables marked: U. S. Lake Survey, discharge measurements, Dry Dock Section, St. Clair River 1899, 1900, 1902; Tables 1, 2, 3, 4, and 5. With the same heading, Table A, the measurements of 1901 showing the adjustment made for abnormal stage of Lake St. Clair, Table not indicated by letter or number, with the same heading, for the year 1908. A table marked: U. S. Lake Survey; hydraulics of St. Clair River; summary of discharge measurements, Section Gorge, Sherman Moore, Jr., engineer, April, 1909; marked Table 5. Table No. 2, summary of discharges, Open Section, Niagara River, F. C. Shenehon, U. S. Assistant Engineer 1906. Table No. 2, same heading. Table No. 1, summary of discharges International Bridge Section Niagara River, F. C. Shenehon, U. S. Assistant Engineer 1906. Continuation of the same table showing measurements, Number 5 to 68, inclusive. Continuation of the same table showing the measurements 69 to 124, inclusive, with such exceptions in the inclusion as noted on the last sheet. U. S. Lake Survey, Preservation of Niagara Falls, elevation of Lake Erie derived from discharge of Niagara River, Inter-

national Bridge, Buffalo, New York. Table 47 in three parts. These are the observations of 1907 and '8. Table No. 1, summary of discharges, Three Point Section St. Lawrence River, F. C. Shenehon, Assistant Engineer May, 1906, in two parts, including observations 1 to 96, inclusive.

Q. These tables show the facts with reference to the original observations upon which these plats are based?

A. Yes. A reservation should be made in making that statement for the St. Clair particularly of certain transfers of water level which are included in the reduction of the observations as for instance between Fort Gratiot, and Harbor Beach.

Q. Just explain that?

A. Where two water gauges are a short distance apart (and when I say short, that may mean as much as one hundred miles) the elevation of one may be derived from known elevations of the other; and the accuracy with which this may be done is so great that it is given the same belief as the best precise levels. In other words, the water surface is a great leveling instrument itself, and two water gauges and the water surface form a leveling instrument, so we can pass from one gauge to the other. This is true also of the equivalent relation between the lake water gauge and the river surface; and some changes have been made in elevations between the G. T. R. Gage near lead of river and Harbor Beach, in reducing these observations. The error in such a case is small. There may be an error as much as one-tenth in the transfers from Dry Dock section to Harbor Beach, one-tenth of a foot. The fall between Harbor Beach and G. T. R. Gage, as I recollect it is 77/100 of a foot; that is the normal ordinary fall.

Q. Now with reference to your checking up of these tables, as has been already indicated, is there any other explanation that you would like to make?

A. No.

Mr. Wilkerson: That covers everything that you wish to know, for the purpose of going over them. The question of actually incorporating these in the record, we will reserve until you gentlemen have the opportunity to go through them more in detail?

Mr. Williams: Yes. You can say now on the record, I think, that there will be no objection made to the admission of these tables, on the ground of their not being the best evidence, by either side.

Mr. Wilkerson: These tables will be taken as if supported by the testimony of the witnesses who made the observations?

Mr. Williams: That is it.

Mr. Wilkerson: And their correctness will be assumed.

Mr. Williams: That is that they are a correct representation of the work of those witnesses.

Mr. Wilkerson: With the additions and explanations that Mr. Shenehon has made as to one or two points here.

Mr. Williams: Yes.

Mr. Wilkerson: Of course it would be unnecessary for us to put them in the record, and it would only encumber the record unless there is some matter concerning which you wish to question the accuracy of our charts, because the way the record stands now we have that summarized on the plat, so that they become immaterial.

Mr. Williams: Unless we want to introduce them.

Mr. Wilkerson: Unless you want to put them in for some reason. I think now there is no question about either the plats that have been already identified or this data, as to its availability for use by either side as the best evidence in the case.

Mr. Williams: That is all that part of the plat which refers to this data. We are going to object to those parts of the plat which contain those scales, as conclusions. We are going to object to this part of the plat on the left side; in the first place, on the ground it assumes to show the difference between a situation with no diversion at Chicago and a situation where there would be 14,000 cubic feet diversion. That is not the issue in this suit. There is only 4,000 cubic feet involved in this suit. All of this we will object to going into evidence at all.

Mr. Wilkerson: I will put a question to the witness about that scale at the side. (Q.) You had that prepared, did you?

A. Yes.

Q. It correctly represents the result of the plat, does it?

A. It represents two parallel scales in which one corresponds with the horizontal side of the triangle referred to before, and the other the vertical side. It reduces to a scale of inches the relation between change of lake surface elevation and change of outflow. It permits the application of the rate of outflow, or increment, to a particular diversion, as 4,000 cubic feet per second, graphically and readily. And its purpose is none other than to make that process easy, and clear.

Q. Is there anything else now with reference to this Exhibit No. 1, in connection with its preparation, or in explanation of it, that you have to add to what you have said already, Mr. Shenehon?

A. The note on the plat states the discharge observations of 1899, 1900 and 1902 are shown by circles; the observations of 1901 are shown by triangles and those of 1908 by squares. The object of this is to distinguish them. The number of observations for each year: 1899, there were 90 measurements of the river flow; 1900, 66 measurements of the river flow; 1901, 36 measurements; 1902, 48 measurements; 1908, 15. This is on the Dry Dock section. In 1908, 22 additional observations were made on a new section not shown on this chart. This shows 219 measurements of the river flow made under conditions approaching normal. I say approaching normal because individual observations might have shown some tilt up of the lake, Lake Huron, to which St. Clair did not immediately respond; but part of these would be where the lake was a little high, and probably an equal number would be where Lake Huron was on the low side. The errors that may come from this are compensating, and the grouping of the observations as has been done would serve to eliminate or offset any error that might be introduced from this cause.

Q. Exhibits 2, 3 and 4 were also prepared under your direction?

A. Yes.

Q. What you have said with reference to the correctness of the observations as represented on Complainant's Exhibit No. 1 relating to the St. Clair is applicable to each of these other plats is it?

A. Yes, with such explanations as the plates themselves bear regarding the number of observations and the grouping.

Q. Let us take up No. 2: Is there anything in connection with No. 2 that you should add by way of explanation?

A. In the case of the discharge of the St. Lawrence, this represents the discharge as it was taken in 1901, 1902, and the relation between elevation of water surface and volume of discharge is for the water surface of the St. Lawrence River at Ogdensburg. The movements of the water surface at Ogdensburg are about two per cent different from those of Lake Ontario itself; that is when the water goes up a foot at Ogdensburg, it will go up a foot and two hundredths in Lake Ontario. A further reservation of statement should be

made regarding this chart that in 1903 one of the outflow channels at the Galops Rapids was dammed by the Canadian Government and the increment of discharge was lessened by that damming. The change in the discharge was 5½ per cent, and it is assumed that for a given stage of the river at Ogdensburg, the discharge after the Gut dam was put in place (and it was put in place in 1903) was 5½ per cent less than it was before. It is assumed that the increment has changed in the same ratio; that where the increment is shown as 28,870 here, it should be lessened 5½ per cent.

While touching on that point, it might be well to state that the 1908 observations on the St. Lawrence River verified the value of the 5½ per cent change within, I think, a half of one per cent. That loss of discharge by reason of the Gut dam was most accurately deduced by water gauge readings in the lower river at the Rapide Plat. The water gauge is read daily and has been for a great many years, and the discharge observations calibrate the weir. The same condition holds at the head of the Long Sault Rapids above Cornwall. There the Canadian authorities read the water gauge daily at noon, and that weir was also calibrated, so that when the Gut dam was put in place by the loss in level on these particular weirs, we knew very exactly what loss of discharge was occasioned by the building of this dam. So it is not an estimate; it is an accurately derived statement; and the corroboration of the 1908 observations is confirmatory of that.

Q. Those are the observations with reference to which Mr. Moore testified on yesterday?

A. Yes.

Q. Is there anything further you want to state with reference to that?

A. I might state that the total number of discharge observations is 93 in that 1901-1902 work.

Q. Is there anything further with reference to No. 2 or with reference to Numbers 3 and 4 that you wish to add by way of explanation?

A. No. 3 and 4 need no explanation, except as the explanations are contained on the sheets themselves. I might state here that the number of discharge observations in 1898 to 1900 at the International Bridge were 101, and in 1907 and '8 there were 118 that were utilized on this chart. Subsequent to this eight more observations were taken last fall, which are not incorporated. That makes a total of 219 observations utilized in this chart. In the case of the Open Section on the

Niagara River, the total number of discharge observations is 121.

Mr. Wilkerson: I think I made my statement broad enough about these original observations to cover all the plats.

Mr. Williams: Yes. It may be understood that what was said at the time of the discussion concerning Plat No. 1 applies to all these plats.

The Witness: Seventeen observations made in 1898 by the Deep Waterways Commission were utilized to this extent.

Q. Observations made where?

A. At the International Bridge, on the Niagara River. They were made under my direction, incidentally. The velocities at the different stations, the twenty-one different stations across the river were used, but in reducing them the coefficients and cross sectional areas, as deduced later and more accurately by the Lake Survey, were used, but to the extent of taking the velocity, the data is Deep Waterways data.

Mr. Williams: Q. That is they were used by applying to them the sections which you had later more accurately done?

A. Yes. It might be well to add that in this work the United States was in a measure collaborating with the Deep Waterways, as they were in the precise levels run on the St. Lawrence.

Mr. Wilkerson: Q. Now, Mr. Shenehon, what do you say as to the extent of the lowering of Lakes Huron and Michigan as a result of the diversion of 4,000 cubic feet of water per second at Chicago, and on what do you base your answer?

A. The lowering would be between two and two and a half inches in my opinion.

Q. And would that answer apply proportionately to the diversions of other quantities up to say fourteen or fifteen thousand cubic feet per second?

A. Yes.

Q. On what do you base that answer?

A. The observations made by the Lake Survey, the discharge observations, with a possible error in the increment of 25 per cent. The observations as platted indicate a lowering of two inches, and in my belief that is the least lowering that is probable.

Q. Why do you say that is the least lowering that is probable?

A. I base that on the fact that Sabin's earlier measurements indicated an increment of about 19,000 and the measurements made at the Gorge section during 1908 by Mr. Moore

indicate an increment in the neighborhood of 20,000. I base it further on the fact that the physical conditions in the St. Clair river are such as to indicate a fairly small increment. That is, a river that is narrow and gorged, and has to get its cross sectional area by depth in large part is more likely to have a small increment, than one with a broad outlet. That point is well illustrated in the Niagara River, where the upper river is considerably narrower than the river at the head of the Rapids at Niagara Falls. The broad river, something like three-quarters of a mile at Niagara Falls, with not much over a quarter of a mile at Buffalo, makes the increment about half at Niagara Falls of what it is at Buffalo, in the upper river. And we have a further illustration of that when we go down to Suspension Bridge and the Whirlpool. There the increment is somewhere in the neighborhood of 9,000, less than 9,000, and the reason for the small increment there is the narrowness of the river about 400 feet; the river is gorged. And the same is true of Suspension Bridge. A fairly similar condition exists at the head of the St. Clair River, at what is known as the gorge there; it has a width of about 800 feet. It has a depth of over 60 feet with a width of about 800 feet.

Another reason why I think the increment is likely to be smaller than 24,000 rather than larger than 24,000 is the certain relations holding between Lake Erie and Lake Huron. The movements of Lake Huron are larger than those of Lake Erie, which would indicate that the increment is smaller. Perhaps those are not very definite reasons for my belief that the increment is smaller than 24,000, but it has influenced my judgment and I believe it to be true.

Q. What would be the effect of the lowering of the level of Lakes Michigan and Huron upon the St. Marys River?

A. Well, the lowering at any point on Lake Michigan would be accompanied by a similar lowering throughout the whole of Lakes Michigan and Huron, and in all harbors and bays, and would extend up St. Mary's River with some small diminution; I should say it would reach the locks with a loss of 20 per cent. That is 80 per cent of the effect shown on Lake Michigan would be indicated in the floor of the Poe lock, or over the floor of the Poe lock.

Q. What is your reason for saying that 80 per cent of that effect would be found there?

A. That is an estimate, and is based in some measure on back water effects in the Detroit River and the St. Clair River,

and in the Niagara River as well. The fall from the level of the water at the locks to Lake Huron is not much over a foot at the present time, and with a deep stream with no rapids, the back water effect, the largest percentage of it would go up. Speaking rather roundly, if 60 per cent of the effect would travel up the Detroit River from Lake Erie to Lake St. Clair, or 66⅔ as the Deep Waterways estimate it, that is up a rise of 3½ feet, it seems very reasonable that 80 per cent would go up the St. Marys River, and if 50 per cent of the effects of a rise on Lake St. Clair would be transmitted to Lakes Huron and Michigan, that is up a rise of about 5 feet the 80 per cent for St. Marys River seems a very safe estimate. Under present conditions, it has not been computed; we have not observations enough. The taking away of the cofferdam in west Neebish has lowered the water at the Sault locks and brought in a new condition of back water effect, and 80 per cent I think is a conservative statement.

Q. Would the effect of a diversion of water at Chicago upon the elevation of the lakes manifest itself immediately?

A. No, it would take some months.

Q. How long would it take for it to assert itself?

A. Taking an increment for the St. Clair River of 23,820 or 24,000 speaking of it roundly, it would take about four years. If the increment were half that, it would only take two years. It varies directly as the increment.

Q. That is to accomplish how much of the total effect?

A. That would be nine-tenths.

Q. It would accomplish nine-tenths of it in about four years?

A. Yes. To get the other tenth would take just as long.

Q. You said you had to do with the measuring of discharges in the Niagara River?

A. Yes, I was in charge of the Buffalo office from July, 1898, until August, 1900.

Q. Give us some information with reference to the detail of measuring those discharges, and also with reference to the extent of the measurements?

A. The first section of the river measured was that under the lower chord of the International Bridge. The International Bridge crosses the river at what is known as Black Rock and consists of nine spans, and these spans were divided up so that each river width of about 80 feet was considered as a small stream by itself. The first three spans were divided into two stations each, and the spans four, five and

six (I am counting from the American side) had three stations, and spans seven and eight, two each, and span nine, one. There was very little flow in the ninth span; the water was very shallow and small current. The elevation of the water surface was determined by water gauges, one on each side of the river. These gauges were of the box and bottle type which accurately give the water surface to 1/100 of a foot. Later on a self registering water gauge was put in the slip at the foot of Austin street, which is about 3/10 lower down the river; that is 3/10 in elevation. The river was sounded at very frequent intervals, I believe as often as ten feet, very accurately sounded to get the cross sectional area, in conjunction with the water surface elevation.

In sounding, the water surface itself was used as the plane from which measurements were made. By that I mean to say that we did not take the plane of the water surface as indicated by the water gauge but the measurement of depth was between the water surface and the bottom, in each position. I state this because the possible curvature of the water surface is eliminated by doing that. The sounding was done with a 140-pound cast iron weight which was of a projectile shape. It was drawn out sharp at the nose and it was slotted at the stern and a tail put in it so that when it was in the current it was held nose-on, with very little current resistance. It was let down by $\frac{1}{8}$ of an inch wire from a reel; the reel having a circumference of exactly five feet. In order to insure the accuracy of the indications of the reel, it was tested before the soundings and built up, so that exactly 20 feet of the wire made four turns of the reel. Under the influence of current pressures the weight sagged down stream a short distance, and to compensate this it was hauled up above the water surface by guys, and a small correction was applied for the inclination of the submerged wire. In 50 feet of water this correction would not exceed, and I think in all cases was less than a half a foot. That is with water running five miles an hour and 50 feet deep, that was the condition. In most of the spans the depth is less and the current is less swift, and the correction amounted to only perhaps 2/10 of a foot.

After getting the cross sectional area by water gauges and soundings, a meter is let down at 3/10 depth, about midway of each of the stations, one at a time, and a second meter was made to traverse every tenth of depth over a number of sections throughout the station, as often as 20 feet in the

width of the river, each 20 feet, and in many cases, as when approaching the piers, more frequently; and the velocity relations were established between this traveling meter and the one that was stationary at the station or at the three-tenths depths of the station, which we call the index. These observations were made in great detail and over considerable periods, and in the end we derive the volume of the water passing per second, when the velocity indicated at the index is multiplied by the cross sectional area, and reduced by a coefficient which is determined by these velocity relations. After the work I have been speaking of, coefficient work, after that has been completed, a discharge measurement consists of taking a velocity measurement, or two velocity measurements as a rule of two minutes length each, on each station, each of the twenty-one stations of the Bridge Section. At the same time a self registering water gauge located in the lake above the head of the river indicates with a precision of one to two one hundredths of a foot the lake elevation at the time. The volume of outflow, as indicated by the current meters and the section gauge, is then determined with respect to the elevation of the lake as shown by the self registering gauge.

Q. Are those observations that you made in the Niagara River embodied in any one of the plates that are in this record?

A. Exhibit 3, International Bridge section.

Q. Those observations were made under your directions, and many of them by yourself?

A. Yes; personally in part and under my direction all of it.

Q. So that you had the opportunity to know very definitely with reference to the care with which they were made and as to their accuracy?

A. Yes, I made the program, and in some part the methods employed, and personally saw to it that every check that would insure the highest accuracy was used.

Q. I think you mentioned some other measurements of outflow you had to do with personally?

A. Yes. After completing the measurements at the bridge section, in order to verify the relations found there, a new section was established in the open river about 1,800 feet below the International Bridge. This is known as the Open Section. In that section there were seventeen stations, each one of a hundred feet in width. When I say "station" I am using it in two senses. The one hundred foot width of the river,

we sometimes speak of as a panel and sometimes as a station; and the point where we observe, the vertical line midway of the panel is spoken of also as the station; but in the Open Section we observed at the four-tenths depth at station in making discharge measurements.

On the Open Section we had water gauges at each end of the section, that is on each side of the river, and when I say on each side of the river I mean the Island side, that is the American side (there is an island coming in there), and the Canadian side. These gauges were constructed so that we could read from the instrument boat, the Catamaran, the elevation of the water surface to 1/100 of a foot, at any time. And as we made our observation for velocity we also read the gauge, one or both. The soundings were made on that section every ten feet by the same methods as indicated for the bridge section except that we needed no guying as we were close to the water. On that section 121 measurements of the flow were made, and are incorporated in Exhibit No. 4.

Q. What was the result of those measurements, so far as the increment was concerned? Was this second set of observations made for the purpose of checking the prior ones?

A. Yes, to verify the prior observations.

Q. What was the result?

A. The volume of outflow checks within 1.3 per cent that of the International Bridge.

Q. What does that indicate to you as an engineer with reference to the correctness of this work, the obtaining of that result?

A. It indicates correctness, that the work is correct.

Q. You have given us your statement with reference to the effect of the diversion of water at Chicago upon the elevation of Lakes Michigan and Huron. What would be the effect upon Lake Erie?

A. That is of 4,000 cubic feet?

Q. Yes.

A. Lake Erie would be lowered. All of the Great Lakes below Superior, below the foot of the locks in St. Marys River would be lowered.

Q. Speaking of the amount of water which it is proposed to divert at Chicago, I take 4,000 because that is the figure charged in the bill, and I assume when you make a statement with reference to 4,000, the statement which you make would apply proportionately to other quantities?

A. Yes.

Q. Within a limit of up to 14,000 cubic feet per second, I will say?

A. Yes.

Q. So it will not be necessary to speak of the effect with reference to all these different quantities, but when you speak of it with respect to 4,000, you will be understood as having your answer apply proportionately to other quantities. Is that correct?

A. Yes, that is correct.

Q. To what extent would Lake Erie be lowered, and upon what do you base your answer? Before you answer that, Mr. Shenehon, going back to the Niagara River, did you take the increment of the Niagara River also, as you did the outflow, those two sets of observations about which you testified?

A. Yes.

Q. How did that check?

A. The increment as indicated by the Open Section is 21,640 and the increment as shown by the International Bridge section is 21,900.

Q. Does that indicate the same thing to you as an engineer as to the correctness of this work, the fact of that agreement?

A. Yes.

Q. Now as to Lake Erie again?

A. I think while we are on increments I would like to say a little something.

Q. All right, if there is any further explanation of that, you may make it now before we take up the effect on Lake Erie?

A. In a report made by me in 1906, I make the increment at mean lake level, 21,720.

Q. What river are you now speaking about?

A. I am speaking of the Niagara River; that is by the Open Section, 21,720.

Q. To whom was that report made?

A. That was made to Colonel Luck, officer in charge of the Lake Survey.

Q. Is it published?

A. No, unpublished. It became eventually a part of the report to the Chief of Engineers for that year, but was not published.

Q. It is referred to in that report?

A. Not in the printed report. The policy of the govern-

ment is not to print technical publications at the present time.

The International Bridge section shows an increment of about 22,000. In these reports, the law of discharge was not taken as an exactly straight line, but the discharge was taken to vary as the 3/2 power of a certain depth at the head of the river. For the Open Section the increment between Lake Erie elevations 569 and 570 is about 19,290 and between elevations 574 and 575 is 23,210. In the plats Exhibits 3 and 4, the discharge line is given as a straight line, and the error of taking it as a straight line is insubstantial, so far as the matters in this case go.

Q. That is by that you mean that there is no substantial difference in the result obtained when you draw the straight line as it is in the plates which have been offered in evidence and when you draw it as a slight curve as drawn in the other computation?

A. As regards the effect on the lake level, I should say whether you take a straight or curved line, whether you use the increments as shown in my 1906 report or whether you use those shown on the plates, the effect on the level would not vary one-sixteenth of an inch; that is taking the lake in the four or five years in which it may be lowered. If you consider the lake at a pretty high stage, then the lake would be tending to lower at a lesser rate, but when the lake is lower, it is tending to lower at a greater rate, and the lowering at mean lake level is the thing that counts.

Q. As I understand one of your last statements—I want to be sure that I am correct in it and if I am not, correct me—you start out with these observations which are put down on these plates. There are two different methods of determining this increment, one used in your report, about which you testified?

A. Yes.

Q. And the other used on the plate?

A. Yes.

Q. I understand you to say that the difference which would come from using the one method of computation rather than the other would not amount to more than 1/16 of an inch?

A. That is right. I want to explain that a little further. Most of these discharge lines are doubtless curves instead of straight lines. There are several reasons for that. There are so many more forms of curves than there are straight lines, only one straight line, the chances are always that it

may not be exactly a straight line. Unless you are splitting hairs, or trying to get down to the last refinement, you are not warranted in using curved lines. I might illustrate that by considering the surface of the earth or the surface of a small pond. We think of that as being a perfectly straight line across. We know it is simply an arc on the globe, of the circle of the earth; it is curved, but substantially and for all practical purposes it is a straight line.

Q. That is if the radius of the circle was big enough, the curved part becomes practically a straight line?

A. The curvature is so slight it does not in any way negative the substantial accuracy of using a straight line so far as arriving at the lowering of the lake levels is concerned.

Q. And for that reason these lines were drawn on the plates which you prepared for the purposes of this case in the interest of simplifying the operation?

A. To simplify the process, that is all.

Q. Is there any further statement you have to make with reference to this increment?

A. I did not give the increment in the International Bridge Section.

Q. Just give that now?

A. Between elevations 569 and 570 of Lake Erie, the increment is 19,540, and between 574 and 575, it is 23,510.

Q. Now we will take up Lake Erie?

A. The effect on Lake Erie of the diversion of 4,000 cubic feet would be about 2¼ inches.

Q. Upon what do you base that?

A. That is based on my work on the Niagara River and my knowledge of the results obtained from that, which is corroborated by the charts.

Q. And by the later observations in 1908?

A. And by the later observations. Yes, those were made under my direction as Principal Civilian Engineer of the Lake Survey. The planning of the work of the preservation of Niagara Falls, the hydraulic work there, was part of my work, and the initiation of it.

Q. What would be the effect on the Niagara River?

A. At Austin street, which is just below Black Rock, about 82 per cent and at Chippewa which is just above the rapids at Niagara Falls about 56 per cent of the lowering of Lake Erie. The lowering at Suspension Bridge or in the pool below the Falls and above Suspension Bridge, would be about 230 per cent, and in the whirlpool about 250 per cent.

Q. What would be the effect of the lowering due to this diversion at Chicago upon the Detroit River?

A. It would be lowered. In the vicinity of the Lime Kilns on the lower river it would be practically the same as in Lake Erie. And as you go further up the river, up towards St. Clair, it diminishes slightly.

Q. What would be the effect of the lowering by this diversion in Lake St. Clair and in the St. Clair River?

A. Computations made by the Lake Survey indicate about 41 per cent of the effect of Huron present on Lake St. Clair and about 45 per cent of the effect of Lake Erie.

Q. And to get the total effect you would take the sum of those two, would you?

A. About 86 per cent of the mean of the two lowerings would give it very closely.

Q. Eighty-six per cent of the mean?

A. Eighty-six per cent of the mean would give it very closely. That is on St. Clair the mean of the effect on Erie and Huron. Other computations show 37 per cent of Huron and 44 per cent of Erie, and that would indicate about 81 per cent of the mean. Perhaps 80 per cent might be a safe statement to make on that, or an average statement, 80 per cent of the mean.

Q. Are those computations made by the Lake Survey published?

A. The computation made by Sabin, the former of the two I give, is published in the 1900 report, page 5398.

Q. Is that the last computation made by the Lake Survey?

A. The computation by Mr. Ray, the latter of the two, I think is as late as anything we have.

Q. Those are the two you had in mind when you were testifying?

A. Yes.

Q. The only thing I wanted to bring out for the information of the gentlemen on the other side was as to whether or not these computations were published and if they were we would give them the references in the record?

A. Mr. Ray's computation has not been published.

Q. But Mr. Sabin's has.

A. And I want to say in regard to getting at the distribution between Huron and Erie as to the percentage of the effect of each, it is a little indeterminate. The total effect on Lake St. Clair, if the effect on Huron was 2¼ inches and the same thing on Erie, 80 per cent would be a very close

approximation to the truth of the effect on Lake St. Clair. But the nature of the reduction with varying gauge readings, is such there is some indetermination as to where the effect comes from, Huron or Erie. The effect of Erie comes as backwater and the effect of Huron is that of less water passing through Lake St. Clair. Less backwater tends to increase the outflow through the St. Clair River, so the thing is a little complicated.

Q. Have you made measurements on the St. Lawrence, of the same nature?

A. Yes, I made measurements in 1900 and 1901.

Q. What were the details of those measurements and the extent of them?

A. A hydraulic section was taken at Point Three Points, which is about twenty miles below Ogdensburg, and very close to the narrowest point in the river, where the conditions are exceedingly favorable for accurate measurements. The river at this point is about 1,700 feet wide and we had seventeen stations or panels on that river. The detail is much the same as the measurement of the Open Section of the Niagara River. We made 92 measurements there and 26 measurements were made at the same place by Mr. Moore during the past season, under my direction. During the winter of 1901, February, 1900, I measured a second section in the St. Lawrence River above Ogdensburg where the river is three-quarters of a mile wide.

Q. How is that section designated?

A. Nevins Point section.

Q. Were those winter measurements?

A. Those were made through the ice in the winter season. As I recollect it, we had twenty stations there or panels, which were 200 feet in width. The current had a mean speed of about one foot per second on this section and the depth I believe was in the neighborhood of 60 feet, mean depth 51 feet. We made these measurements for discharge there. The conditions for soundings, of course, on a section of that kind were very excellent for accuracy; and the conditions for velocity measurements were not as good; the slow velocity of one foot per second is more difficult to measure. The winter measurements checked the summer measurements within less than one per cent.

Q. Was the work which you did on the St. Lawrence River embodied in any one of these plates that has been prepared here?

A. The winter measurements?

Q. Yes.

A. You mean the summer or winter measurements?

Q. Either one of them?

A. The 93 measurements of which I have spoken are incorporated on Exhibit 2; those made at the section Three Points.

Q. And the winter measurements check with the others that you have stated?

A. They corroborated the summer measurements so far as volume is concerned. The range was not sufficient to determine anything regarding the increment.

Q. What would be the effect of the diversion of this water at Chicago upon Lake Ontario and the St. Lawrence River?

A. It would lower them; lower Lake Ontario and the St. Lawrence River to the Gulf of St. Lawrence.

Q. And to what extent?

A. The river at Ogdensburg, for 4,000 cubic feet, would be lowered 1¾ inches; and substantially the same on Lake Ontario. In the lower river in the approach to the Morrisburg Canal above the Rapide Plats, it would be 50 per cent. greater, 150 per cent. of that. I am stating this roundly. Lake St. Francis, as I remember it, the lowering would be a little less, but that is in Canadian territory, and I do not know that we need to go into that.

Q. You have referred once or twice during the course of your testimony to the building of the Gut dam in the St. Lawrence river?

A. Yes.

Q. And the measurements made for the purpose of determining the effect of that upon the increment and the volume of outflow. I wish you would state a little in detail what the facts about that are?

A. I did state it.

Q. Is there anything in addition to what you have already stated?

A. By means of the measurements at the Three Point section, we write out the outflow relations for the river over the Rapide Plat. That is another weir and outflow, just the same as the Galops Rapids is above, and we did the same thing, also at the Long Sault Rapids; so we have now the Galops Rapids, the Rapide Plats and the Long Sault Rapids. There is water passing over three different weirs. We calibrated these three weirs. The Galops Rapids Weir was interfered with by the building of the Gut dam, but the other two were free to meas-

ure the water, so the loss of outflow in the Galops Rapids was shown by a lowering of the water at the head of the Rapide Plats and the head of the Long Sault Rapids. The lowering appeared as the dam went in; it is very determinable. I ought to say in this connection that preceding the building of the Gut dam, I made a report on what the effect would be if they did build that dam.

Q. Based upon what?

A. My general knowledge of the conditions.

Q. And upon observations that had been made before that time, and general methods?

A. Yes, based upon the discharge measurements of the St. Lawrence River. The conditions were such that an accurate statement could not be made. We had to scale off the cross-sectional area of the Gut; we had the soundings there.

Q. Your computations were borne out, were they, by the actual observations?

A. It came within the limits stated. The actual rise of Lake Ontario by reason of the Gut dam was about five inches.

Q. You used a phrase that I think counsel on both sides would like to have you explain a little more fully. You spoke of calibrating the weir?

A. That is simply taking the discharge measurements and gauge readings at the same time; we get a relation between the gauge height and the amount of flow. It does not have to be necessarily in the lake; it can be in the river at any point. We have calibrated the weirs of the Niagara River at the head of the Rapids, and again at the Suspension Bridge and the Whirlpool, as I have stated earlier. Each rapid in a river, where there is a pool above it, becames a measuring instrument to estimate the flow of the river. While you measure in one place, the same amount of water goes through the whole river; if you have gauge readings at different points, you get the relation between the gauge readings for any point and the volume of outflow, and you can make a plat, such as in this case, Exhibits 1 to 4.

Q. What do you say as to the precision of river gauging done by the Lake Survey?

A. I consider a discharge measurement, or rather a series of them, to have a precision of 1 to 2 per cent.

Q. What is the reason why you think it has that precision?

A. That is in volume, not increment; the precision of the increment is not as great, perhaps 10 per cent. And as I have already stated, in the case of the St. Clair River, the incre-

ment may be an error of as much as 25 per cent. The reasons for my belief in the precision of volume is the corroboration that has invariably accompanied the measurement of duplicate sections, that is, the measuring of two sections in the same river. I speak now of the recent Lake Survey work, the work since 1896. In the Niagara River, as I have already testified, the second section corroborated the first within about 1.3 per cent. The precision of the summer measurements on the St. Lawrence River were corroborated by the winter section. The measurements on the power canals at Niagara Falls, made by Mr. Moore, concerning which he testified yesterday,, as these were made under my direction and with my knowledge, I presume it is proper for me to state those?

Q. Certainly.

A. The second section corroborated the first on the Niagara Falls Power Company's canal within half of 1 per cent., and in the case of the hydraulic canal, that is the Schoelkopf Canal, the second section corroborated the first within 1.3 per cent. In the St. Clair River, the measurements made under my direction by Mr. Moore in 1908 corroborate the earlier measurements within 2 per cent.; show about 2 per cent. less flow than in the earlier measurements. The evidence given by these measurements at two sections on a stream, canal or river, are very strong confirmation to my mind of the correctness of the method employed. In 1906, I urged upon the Principal Assistant Engineer of the Lake Survey the advisability of making tests of the current meters, to see whether or not they did give the true velocity of the water. I thought the Lake Survey had so many velocity measurements that in its own records it ought to have a test of the current meters, and to get at the clear truth, to apply a correction for the meters or have a co-efficient of correction, so that our data would be gotten down to the limits of precision, which was what we were working for in all respects. And I made tests on the Detroit River at Fort Wayne, or abreast of Fort Wayne, to find out whether or not the velocities shown by the current meters were the actual velocities at which the water was moving, and 76 measurements, traverses of colored water over a 200-foot base, showed that the current meters indicated the same velocity as the colored fluid was traveling, within one-fifth of one per cent. As the result of those observations my report to the Lake Survey was that we needed to make no corrections of our discharge observations for the meter error.

I can go into that more in detail if it is necessary. I have a report on the subject here, as a matter of fact.

Q. You have your report here, have you?

A. Yes, I have it.

Mr. Wilkerson: We will have it marked as an exhibit for identification, and if you gentlemen want to refer to it, or want to incorporate it in the record, you can do that hereafter. The paper produced by the witness is marked Exhibit No. 6 for identification. It is headed: "Current Meter Tests."

Whereupon document referred to by counsel was marked for identification "Government's Exhibit No. 6."

Q. In order to have a complete explanation of your reasons for saying that the measurements made by this current meter are accurate, you may read such portions of that paper as will explain, or add to what you have said already, and you may have the entire report, if deemed advisable hereafter, incorporated in the record.

A. In making these tests we used two of our steel pontoons. They are part of our pontoon sweep. These have overhanging decks and we extended the overhang of these pontoons further still so that we could drop a meter twelve feet beyond the hull, so as to get away from the hull influence. Then we took two of these pontoons and hung them in the current, one 200 feet below the other; the first suspended by an anchor above, and the second suspended from the first by two galvanized iron wires. On one of these wires a 200-foot length was laid off and beads were soldered on, and this 200-foot length was tested by steel tapes when the system was hanging in the river, or floating in the river current. Then we put one of two current meters about abreast of the upper up-stream bead, and the other one just below the down-stream bead. We injected with a bicycle pump about four ounces of a strong fluid bluing, or a strong solution of analine red; we tried both. This was injected in the river above the up-stream meter, and in injecting it, the bicycle pump was moved along at about the current speed, so that no change in the velocity of the colored water would take place. This ball of colored fluid, or the water itself which was colored by the injected bluing or red, was timed between the first meter and the second, with a stop watch, and the current meters were operated at the same time, which gave us two sets of velocities, the velocitiy shown by the colored fluid and the velocity indicated by the spinning wheels of the meter. If the two agreed, the test seems very

complete. I have already stated that 76 of these traverses, or 76 different colored balls going over the 200-foot base, the mean of these shows that the meter indications were within one-fifth of one per cent. of the velocity shown by the fluid.

These meters were rated immediately before the test on the still water base, following our customary methods.

Q. How do you rate a meter?

A. A meter is rated by moving it through still water over a 200-foot base, ordinarily. That is, a wire is stretched across a reservoir, or some still body of water, and on this wire are two beads soldered about 200 feet apart. The meter is suspended ahead of a boat, ordinarily ahead of a skiff, sometimes ahead of a catamaran or between the hulls of a catamaran. And in some of our rating, we even work on the ice, by suspending the meters through a slot in the ice. The meter is made to traverse this 200-foot base at a large variety of speeds, that is, such a variety as we are likely to find, or do find, in the stream that we are measuring; and the propeller wheel actually shows the relative motion between the water and the instrument. And our test indicated that it does not make any difference whether the water is moving, and the instrument is at rest, or the instrument is moving and the water is at rest; the relative movement is what the propellor shows. In stating this, I make the reservation that the flowing water should be fairly smooth water. I do not mean to say you could go out in rapids and measure the velocity very closely, with a float, or anything else, or with a current meter.

Q. What do you think about the precision of your observations as to soundings?

A. That is well within 1 per cent. in all cases.

Q. Why do you say that?

A. That is involved also in the check of two sections of a river. If the soundings were not accurate, why the results would be likely to diverge on two sections. We have also sounded the same sections a number of times over, and the precision indicated is very great. That came out in the resounding of the spans of the International bridge. The difficulty of sounding becomes greater as the water is swifter and deeper; and in the third span of the International bridge the water is running about five miles an hour and is about 50 feet deep; and the second sounding corroborated the first within one-tenth of a foot, that is, the mean sounding. Then the St. Lawrence, the duplicate soundings there, come very close. I do not know just how close it was, but it was within a

tenth of a foot, the mean. The soundings are certain, as we make them, to be well within 1 per cent.

Q. What do you think about the precision of the observations which you made with the water gauges?

A. That cannot be expressed as a percentage, as that means very little; it should be stated as absolute. The water gauge readings as made by me for the Niagara River and for the St. Lawrence do not have an error exceeding one-fourth of an inch on the water surface. And when I say that, I mean for individual discharge measurement, the mean, or the readings which give the final result are less in error than that; I should say within one one-hundredth of a foot, or one-eighth of an inch. I have already stated it is my opinion on the St. Clair River that the water level transfers may have made an error of as much as one-tenth of a foot, in some of the readings. There are some cases on some of our gauges in the lakes where settlement of a pier on which they are located may temporarily give us incorrect readings; but we test our gauges twice a year with a spirit level, we have inspections, and as I have already said two water gauges on one of the Great Lakes with a water stretch between, that forms a leveling instrument; and we are constantly watching our gauges. As an illustration of how we can detect from one gauge an error in another, I might state a case that occurred on Lake Erie. The District Engineer's office maintains a self-registering water gauge of the Lake Survey type at Amherstberg. The Lake Survey maintains a similar gauge at Cleveland. Upon examining the records at Cleveland and Amherstburg, I found that something was wrong with the Cleveland gauge. I told them that the Cleveland gauge was showing one-tenth of a foot too low; that is, about an inch and a quarter too low. An examination of the Cleveland gauge was made and they found a small leak in the float. Upon emptying the float and testing the gauge, the actual error of the gauge was found to be from that cause 11/100 of a foot, that is, an inch and three-eighths. That indicates how from one gauge we can state whether or not things are going on right at another; and a process we are watching pretty carefully.

Q. I do not know whether I quite understood what you said about the settling of the piers?

A. I mean that if a water gauge were located on a pier as at Milwaukee, and that pier should settle as piers sometimes do, that gauge might give an incorrect result for a while; but we are watching for those things.

Q. Are those errors involved in the discharge measurements?

A. No, those do not involve the discharge measurements. During discharge measurements, we are watching things with a care that we do not exercise at other times; everything is checked up very carefully frequently.

Q. You are just stating something that might happen, that did not happen in connection with any of these measurements that we have here under consideration?

A. No, that don't affect the measurements under consideration.

Recess to 1:30 p. m.

Parties met at 2:30 p. m.

Q. In connection with these plates about which you have testified, you made reference to the number of observations which had been made, laying stress upon that as one of the things to be taken into consideration in your opinion as to the accuracy of the result. I wish you would explain a little more in detail just what the effect of considering a large number of these observations is in eliminating any mistake which might appear if only one or two or three observations were taken?

A. In the case of the Niagara River, including both the International Bridge section and the open section we have 353 individual, separate measurements of the volume of flow of the river. The length of time over which these observations extended gave us a considerable range of Lake Erie stage. We have nearly four feet of range. The number of observations mean that we used not only a number of different current meters, individual meters, in making the measurements, but the rating of these meters was slightly different from time to time. That is, we would rate the meters and make a certain number of measurements; rate the meters again and make some more measurements and so on. And in the end this has the effect of eliminating instrumental error. Then the other minor errors that might enter into the work, there might be an error in an individual case in the gauge reading; there might be a clerical error in taking it off, but in the great multiplicity of measurements these are eliminated.

Q. Is what you said with reference to the number of observations in connection with the determination of this particular result a thing that is peculiar to this computation, or is it something that applies generally to scientific observations?

A. It is a fact that is general; the number of observations, within limits, increases the accuracy or the precision of the result. I want to make one correction in a statement that I made, I did not make it specific, on the increment of the Niagara River.

Q. You may make that correction.

A. I stated the possible error in the increment of the St. Clair River is 25 per cent., and in my judgment it would be below the increment as shown; that is, the increment would be less rather than greater, for reasons that I gave. And on the St. Lawrence River, the error in increment is probably 10 per cent., but in the Niagara River not over 5 per cent. That 5 per cent. is what I failed to state.

Q. When you were speaking of the degree of precision?

A. Yes, and I perhaps should give the reason why I say that, the range of four feet, in the case of Lake Erie, on the Niagara River, gives a high precision in the trend of the line, and on that the increment is based. In the case of the St. Clair River, with a less range, the exact inclination of the line is less determinate; that is one of the factors. On the St. Lawrence River, we had a range of about 2.4 feet which gave us a good determination, but not as good as the range of four feet on the Niagara River.

Q. What would be the effect of the diversion of this 4,000 cubic feet per second at Chicago on the water power in the St. Lawrence and Niagara River.

Mr. Williams: I object to that, for the reasons previously stated.

A. The fall of the Niagara River from the intake of the Niagara Falls Power Company to the level of the river at the portal in the gorge is about 220 feet. That means for each cubic foot per second of water 25 horse-powers, theoretical horse-powers; that is the potential in the water. For 4,000 cubic feet that would be 100,000 horse-power. The efficiency of turbines and the conditions at Niagara Falls are such that we may expect as high an efficiency as 80 per cent. of that. I should say 80,000 horse-power would be the amount of power in the fall at the cataract, that is, in the rapids above the cataract and at the cataract of the Niagara River. That is on the turbine shaft. The Whirlpool Rapids and the lower rapids of Niagara River have an additional fall of about 88 feet, and 4,000 cubic feet per second would mean 40,000 horse-power theoretical, or 32,000 on the turbine shaft. On the St. Lawrence River the Long Sault Rapids alone has a fall of

about 50 feet, and the loss of horse-power there by the abstraction of 4,000 cubic feet would be somewhere in the neighborhood of 23,000 horse-power, or 18,000 horse-power on the turbine shaft,—assuming the same efficiency there. The investigations, the hydraulic investigations of the Niagara River, which were very extensive and are still in progress, for the preservation of Niagara Falls, has a bearing on the matter of water power at that point. We were ascertaining in that investigation the effects of diversions of water for power purposes.

Q. Have you given any consideration to the question of the effect of ice on these rivers, the St. Clair, Niagara and St. Lawrence, on the outflow through the rivers?

A. In my report of 1902 I make a discussion of the ice effect on the St. Lawrence River; and it is found there that the month of December the ice has no retarding influence on the outflow. January, February and March are the months and the only months that have an influence on the outflow. In the Niagara River, the effect of the ice is less marked, and some discharge measurements were made during the ice season. We made 27 measurements during the winter season, and those show somewhat smaller flow during the winter season. The observations on the Niagara are not extended enough nor the conditions constant enough to determine the ice effect. As regards ice on the St. Clair River, if it is proper to do so, I would like to read an extract from the report of the Deep Waterways, 1896.

Q. You refer now to what report?

A. This is the earlier Deep Waterways Board, not the one referred to in my former evidence.

Q. Let us get the exact title of the book?

A. This is United States Deep Waterways Commission, bearing the date: Washington, Government Printing Office, 1897. The Commissioners were James B. Angell of Michigan University, John E. Russell and Lyman E. Cooley. Cooley, I believe, is the technical man, and he is also, I think, or has been, connected with the Drainage Canal. It is page 21.

Mr. Williams: Before Mr. Shenehon reads that, I would like to have him state whether or not the opinions expressed there or the facts stated there coincide with his own opinion.

Mr. Wilkerson: I thought I would have him indicate the portions of the report to which he refers, and then have him make such statements based upon his own investigation as he

sees fit. I thought that was preliminary to some statement he was about to make. Am I correct in that?

Mr. Williams: There is a part of the report he desires to make his own statement. I have no objection to that but I want Mr. Shenehon's judgment and not that of these gentlemen, unless he has made sufficient investigation so that he feels he has an opinion which coincides with the opinion expressed in the report.

Mr. Wilkerson: Let us first have the parts of the report. Read the parts of the report, Mr. Shenehon; then we will see what develops after you read it?

A. The paragraph marked E on page 21: "The average ice season in the Straits of Mackinac is from January 6th to April 15th, or ninety-nine days. It will thus be seen that through navigation is limited by the closing of Lake St. Clair and the opening of Mackinac, or from December 17th to April 15th, a period of one hundred and nineteen days. The Mackinac ice is understood to be largely the accumulated drift of the two lakes."

On page 199, the same report: "The average dates of closing and opening of St. Clair Flats Lighthouse, Michigan, is December 15th, and April 4." That, I believe, is from official records, and the tabulation goes into that more in detail. My own belief is that the ice season on the St. Clair River is ordinarily between, say December 15th and April 15th. Occasionally the ice does last through April, and I believe there are some records of its holding into May; 1901 was a case in point.

Q. What is that ice effect?

A. It is a lessening of the discharge through the ice retardation.

Q. What is the effect of that upon the lowering which would be caused by the diversion at Chicago?

A. Whatever retardation comes from that and whatever lifting of the Lakes Michigan and Huron there is, is something I should say navigation was entitled to irrespective of the Chicago Drainage Canal. If the ice shuts off half the flow of the river, as it does at times, the presumption is—and I state this only as a presumption—that the increment is lessened. And if the increment is lessened during that period, the tendency of Lakes Michigan and Huron is to lower at a greater rate than indicated by the open season increment. By that I mean that if the increment becomes 12,000 instead of 24,000, and that should be a continuous condition, the low-

ering would be four inches for 4,000 instead of two inches for 4,000; and during that period that the ice is in place, the tendency of the lake to lower is greatly due to the Chicago Drainage Canal. It is rising at the same time, but the drainage canal effect is towards a greater lowering than indicated by the open river flow. We have no observations that very clearly show that is the case with the increment, and I state it as a presumption. It looks that way to me.

Q. Is there anything else now that you have in mind, with reference to the ice effect in these rivers? Is there anything you have knowledge of that you have not stated?

A. I do not recall any other fact.

Q. You have covered that condition?

A. I think so.

Q. What knowledge have you on the subject of scouring in the St. Clair River?

A. The observations made under my direction by Mr. Moore last fall, 1908.

Q. Did you follow that work closely?

A. In a general way; not very closely. I knew the results.

Q. I mean with reference to the methods used?

A. Yes, I instructed him regarding the methods to be used and the sections to be sounded.

Q. And the observations which were made were the ones about which you testified yesterday, as the result of your directions?

A. Yes.

Q. What was the result of that investigation?

A. No scour; taking the sections as a whole there is no scour indicated. By that I mean no lowering of the river at that place in the period between 1901, I think, and 1908. I believe in one section the bottom seems to be a little deeper and there is a little less water, but there seems to be no evidence in the whole thing of scouring. There is a movement indicated of certain parts of the river bottom. I know of no evidence of scour in the St. Clair River as a whole, or in the head of the St. Clair River, that is making the discharge any different now than it was in 1898. The discharge observations made in 1908, the corroboration of those with the earlier discharges seems to be evidence of no change of regimen in the river.

Q. What can you say as to the effect on Lake Erie of the diversions at Niagara Falls?

A. Up to the present time it is practically nothing; that is,

Lake Erie has not been affected; while the diversions have caused some lowering of the river above the rapids, certain other elements have tended to compensate that lowering; and any lowering of Lake Erie that has resulted is exceedingly small.

Q. What other outlets in Lake Michigan and Huron are there other than the St. Clair River and the Drainage Canal?

A. I know of none.

Q. Is that a subject to which you have given some consideration?

A. In a humorous way.

Q. What do you say as to that for Lake Erie and Lake Ontario?

A. .Lake Erie, of course, has the Erie Canal and the Welland Canal in addition to the Niagara River; and Lake Ontario has no other outlet than the St. Lawrence River.

Q. When you say you do not know of any other outlet, by that do you mean that nobody claims to have knowledge of any such outlet as that?

A. I know of nobody.

Mr. Williams: Let the record show an objection to the counsel asking the witness as to what somebody else claims.

Mr. Wilkerson: Well, what is the present state of knowledge on that subject, so far as you know?

A. I know of no claim that there are any subterranean outlets, if that is what you refer to.

Q. I mean by anybody who claims to have any knowledge on the subject.

A. I know of nobody that claims that there is such an outlet.

Q. In this work in which you have been engaged, have you had any occasion to give consideration to matters relating to data on rainfall, evaporation?

A. Not large consideration, no.

Q. Well, have you given any consideration to it?

A. It has been brought to my attention. I understand that it is one of the elements in an observation of lake levels, if you have adequate data, to take the rainfall and the run-off and the evaporation, and co-ordinate them with the discharge summer and winter and arrive at the lake level. I have never thought that in evaporation, particularly, we had any data that would permit us to figure in that way.

Q. You have studied it with a view to reaching a conclusion as to the reliability of those observations, have you?

A. Yes, I have an opinion on that.

Q. For such a purpose?

A. Yes, for such a purpose. I have an opinion on that.

Q. I wish you would state what that is and your reasons for it.

A. Observations on evaporation have been conducted in reservoirs on shore, and they are not extensive as I know them. We have no observations in mid-lake areas, on an area of the lake that is surrounded by water on all sides is likely to be very different from evaporation in a reservoir on shore. And any attempt to state with any definiteness what the evaporation is on any one of the Great Lakes has little weight in my opinion.

Q. I think you covered perhaps completely the point of the reliability of the data on outflow during the ice season, did you not? A. We haven't very definite knowledge for any particular year as to what the effect may be. Sabin on the St. Clair river made observations for flow during ice periods, and I believe that is all we have, on the St. Clair River. I have rather definite opinions on the St. Clair River, you understand, as I before testified. But one of the years that Sabin considered and made observations in was the year 1901, which was the most abnormal year as regards ice that I have any knowledge of; and I say that, after an examination of the elevation of Lake St. Clair with respect to Lake Huron. The effect of ice is to build up Lakes Michigan and Huron at the expense of Lake St. Clair, and after a period of this ice retardation, Lake St. Clair naturally is low; its supply has been cut off and the water drawn out of it. The same is true in a lesser degree of Lake Huron. 1901 is doubtless the most abnormal of the recent years as regards ice conditions; that is the ice retardation was greatest and continued longest into the spring. As regards rainfall, the absence of rainfall, stations upon the open lake areas themselves and the thin distribution of stations through the Canadian part of the water shed make the use of rainfall observations rather uncertain, and when I say that, what I mean is, that I do not see that observations on rainfall and evaporation and the winter flow of the St. Clair River could be used to detect the presence or absence of the effect of the present flow of the Chicago Drainage Canal. The two or three inches that might be the effect of the Drainage Canal, or that would be the effect of the Drainage Canal, masked by the conditions.

Q. What have you to say as to the effect of the fluctuations

of the lakes due to natural causes in making this loss of two or three inches which would result from the diversion of this water more or less serious?

A. I do not see that the fluctuation has any bearing on the case.

Q. Why do you say that?

A. Because whatever the water level is, if it had been lowered, say two inches, by a diversion, you would still be short your two inches where you needed it, in the critical places. The natural fluctuations due to winds and to seasonal conditions are independent of the drainage canal, and the loss in draft is always measured by the amount of the lowering; you are always two inches closer to the bottom in such a case, whether the lake is raised or whether the lake is tilted up or not; you are always two inches closer to the bottom than you would be otherwise; and when you are running over critical areas two inches may count. Perhaps I should say: when you are attempting to run over critical areas.

Q. As to the effect of the loss of two or three inches in the draft of vessels, do you give any consideration to that, do you add anything to the statements that have been made already on the subject, and do you know the statements that have been made?

A. I have been familiar with the subject for some time and I have spoken of the loss of draft or the loss of carrying power on one of the large lake freighters, due to loss of draft, as about a thousand tons (of 2,000 pounds) to the foot. That would be 83 1/3 tons to the inch. That is an approximate statement. That is, between say 19 and 20 feet; that is near the load limit.

Q. What do you mean by critical areas, critical places?

A. The areas that are shallow, and where the vessels passing are close to the bottom. In that I should extend it to areas where vessels will be close to the bottom when the deeper drafts on the lake, that are certain to come, are realized.

Q. I wish you would explain that a little in detail, telling us what some of these critical places are now; what changes there are likely to be and what the critical areas are that will be affected by that situation; and where the points are that this difference of two or three inches will make a difference in navigation?

A. The floor of the Poe lock is one of the critical points at the present time. The north end of Lake Michigan is an intricate place for navigation, with a good many shoals. And

when a shoal is two inches nearer the surface by the lowering of the lake level, it becomes more of a menace. The vessels in thick weather sometimes get astray, and loss of draft on a shoal may mean a very serious thing to a vessel. The Manitou Passage in Lake Michigan is a place of the same kind; Gray's reef passage, Sturgeon Bay canal is a critical point, and the entrance to Green Bay is a place where a vessel is likely to get into trouble. The foot of Lake Huron approaching the St. Clair River is another place; also Lake St. Clair; the foot of the Detroit River and Bar Point, which is just beyond the Detroit River, and the west end of Lake Erie; and more particularly that part of Lake Erie leading towards Toledo. The west end of Lake Erie is shallow. When the new lock is built at the Sault, giving greater drafts, the Poe lock will cease to be a critical point; and when the Livingston channel is built in the main Detroit River that will cease to be a critical point. But these others remain; these are fixed and that is what I mean by saying that the points that are critical at the present time, after improvements have been made permitting deeper navigation, those that are safely passed over now, two inches of lowering will reduce their efficiency.

Q. With reference to these plates that you have explained Mr. Shenehon, and with reference to the statements which you have made as to the effect of the diversion of this water, is there anything further that you have to add that suggests itself to you now, or any reports you have in mind that you wish to refer to, that bear on this matter? You think you have covered the ground now as far as you recall?

A. I think so.

Mr. Wilkerson: If there is anything in the way of explanation, or anything Mr. Shenehon wishes to refer to or put in, after reading over the testimony, I can recall him for that purpose.

Mr. Williams: Yes.

Mr. Wilkerson: With that reservation, you may cross-examine.

Mr. Williams: Before proceeding with the cross-examination, we have now introduced as an exhibit this chart showing lake levels. What I desire now is to have it appear in the record that the data from which this chart is compiled, in the way of published data concerning lake levels may be used by us without any objection as to its being the best evidence. The lake elevation observations are shown in the published reports, subject of course to the records from time to time. We

do not want to be obliged to call the men who read the gauge, if we want to show some of those lake elevations as published.

Mr. Wilkerson: You mean you would like to have the opportunity of checking this as against the data?

Mr. Williams: You may put it that way, although we have no question about it. But suppose we wish to make the computation concerning something or other on these lakes, where the scale is not sufficiently accurate to get what we want. What we want would be the opportunity to go back to the table of monthly means, which they have, and to use those tables rather than this chart.

Mr. Wilkerson: I suppose as to any particular data, you can furnish, on reasonable notice, the data which you have in the office?

Mr. Shenehon: Yes.

Mr. Wilkerson: I can see no objection to that.

Mr. Williams: All we want is, if we wish some of that data we will not be obliged to verify it by calling the men who made the reduction, but it will be accepted as evidence.

Mr. Wilkerson: I take it we can have the same understanding with reference to that as we had concerning the data on which the charts are based.

Mr. Williams: That is all we want.

Mr. Wilkerson: In other words, we take the records of the office here with the same effect as if the man himself were put on the witness stand and produced the data?

Mr. Williams: There is one other point: There is a regulation of the Engineer Corps that they shall not give out information in matters of this kind to parties engaged in suits against the government, so that it must be agreed to here.

Mr. Wilkerson: Of course you are entitled to it, because you would have the right—

Mr. Williams: I do not think that is the government's attitude, but I understand there is that rule.

Mr. Wilkerson: This chart having been produced, you are entitled to the data if you want it, for the purpose of cross-examining the witness who produces it. All that you have to do in order to get any data that has any bearing on this case is to let us know what the particular data is, and I think I am safe in saying we will let you have it, if it is in existence.

Mr. Shenehon: I see no reason why that should not be done.

Cross-Examination by Mr. Williams.

Q. The Livingston channel to which you referred is an improvement now in progress on the Detroit River, is it?

A. Yes.

Q. What is the nature of that improvement?

A. The Livingston channel is a proposed channel under improvement at present, passing to the westward of Bois Blanc Island. The present channel runs to the eastward of Bois Blanc Island. And this channel is intended as a channel for downbound traffic, for heavy laden traffic coming down. It starts in above the Lime Kiln crossing above Stony Island and runs out to the Detroit River light.

Q. Is that in American or in Canadian waters?

A. It is in American waters.

Q. What is the extent of the improvement; in other words what are the dimensions of the proposed channel, what is the proposed depth and width?

A. Three hundred feet width, and about 24 feet depth.

Q. What is the present depth of water along the course of the proposed channel; that is the original depth without the improvements?

A. Anywhere from 4 feet to 21, 22 feet, 27 feet in places there.

Q. This improvement is being carried on by what method, dredging?

A. The rock cutting in the vicinity of Stony Island is cofferdammed, and being taken out in the dry.

Q. And the remainder of it?

A. The balance is being taken out by dredging.

Q. What is done with the spoil, the excavated material?

A. It is being put into spoil banks, and I believe into compensating the loss of increased flow due to that channel in the river.

Q. What in your opinion will be the effect of the construction of the channel on the level of Lake St. Clair?

A. I cannot form an opinion on that, because I do not know the extent of the compensation. I think the intention is to put sufficient compensation in to take care of the additional channelway, or flow area, so that no change will be made in Lake St. Clair.

Q. Will the cross sectional area of the Detroit River be increased by the construction of this channel?

A. It will be lessened, as I understand the compensation.

Q. What compensating works are contemplated, other than the depositing of the excavated material in the shallower parts of the river?

A. None that I know of.

Q. If there are no other compensating works contemplated, would you say that the excavated material deposited in the shallow parts will take up more space and reduce the cross sectional area any more than it did in its original location?

A. I have not given sufficient study to that to give an intelligent opinion on the subject.

Q. Assuming, Mr. Shenehon, that in the construction of this channel the excavated material is taken out and deposited in the shallow parts of the river, and that nothing else is done for the purpose of compensating for the new channel, what is your opinion as to the effect of that work upon the amount of water flowing through the channel, as changed by the new work?

A. I have not investigated that sufficiently to give an opinion that would be of any weight.

Q. You have no opinion then, I assume, as to the effect of this work upon the level of Lake St. Clair, or upon the depth of water over the critical areas?

A. In Lake St. Clair you mean, and in the Detroit River?

Q. Yes.

A. My only understanding of the thing is that the compensation will be complete.

Q. And that therefore there will be no change?

A. There will be no change.

Q. In the cross sectional area, or the amount of water—

A. In the level of Lake St. Clair.

Q. —or the amount of water flowing through the Detroit River as modified by this channel?

A. Yes.

Mr. Wilkerson: Who is constructing this channel?

A. The United States engineer office for this district.

Q. It is a government improvement, is that right?

A. Yes. I should add that investigations regarding the water levels of the Livingston channel have been instituted by Col. Townsend and Major Kellor; and Mr. Ray has made some figures on the subject. I have given little attention to it myself. The intention is, however, to compensate.

Mr. Williams: You have testified with reference to the Neebish channel in the St. Marys River?

A. Yes.

Q. What is the nature of that improvement?

A. That is a new downbound channel in the west Neebish of the St. Marys River.

Q. What was the original depth of water approximately in that part of the river where this channel was constructed?

A. I could not testify to that without looking it up.

Q. Passing that for the moment, what is the nature of the dimensions of the new channel? Is it completed?

A. Yes, it is completed.

Q. When was it completed?

A. It was completed in winter of 1907-8.

Q. What are the dimensions of the new channel, width and depth?

A. I believe it is 300 feet wide and 22 to 24 feet in depth. I am not certain of the depth.

Q. What was the nature of the excavation there?

A. That was rock, with mud in upper approach.

Q. Rock excavation?

A. Yes.

Q. What was done with the excavated rock?

A. I am testifying in regard to this without having seen it since it was started, or completed; simply on general knowledge. I have not followed the thing closely and my testimony cannot be very accurate regarding the dimensions there.

Q. Do you know whether or not it was intended or attempted to make any compensation there?

A. I think not.

Q. What was the effect, so far as you know, of the construction of the channel upon the level of the water at the foot of the locks?

A. The effect was to lower it.

Q. To what extent?

A. I am not positive. I do not think the data is sufficient to enable us to state accurately. It may be as much as two or three inches; I believe it was fully that.

Mr. Wilkerson: That was a government improvement also?

A. That was a government improvement, yes. As regards compensation in St. Marys River at the West Neebish, I think an attempt to compensate there would have created currents in the channels that would have made navigation difficult.

Mr. Williams: The original depth was the question that you did not wish to answer until you had seen that document which you now have?

A. Make that 24 feet.

Q. That is for the original depth?

A. No, that is the finished channel.

Q. The finished channel?

A. Yes.

Q. Now the original depth?

A. The original depth is about 15 or 16 feet.

Q. What is the range from the minimum to the maximum, just generally?

A. From four feet, and some rocks are indicated above water so we will have to call it zero; from three to four feet, to 16 or 17.

Q. Now you have before you a map here showing another channel on the easterly side?

A. That is the middle Neebish.

Q. When was the work constructed?

A. The Hay Lake channel was opened about 1894, a little before the opening of the Poe lock. The Poe lock was opened in 1896, and my impression was that the—

Q. It was prior to 1896, that is near enough?

A. The Hay Lake channel was opened, the Northwest opened it when I went up on her, which was in the neighborhood of 1894. Some vessels were running through prior to that.

Q. Now, Mr. Shenehon, with the map before you, can you testify briefly what the original depth was along the course of the Hay Lake channel, and what the improvement consisted of?

A. That is the middle Neebish you are talking about now?

Q. Yes?

A. The original condition is not shown on this earlier chart here, but I should say it was not very different from the condition in the West Neebish. The old channel, the East Neebish, was the original channel, and they had 12 feet of water in the old days; and there was less coming up through the middle Neebish.

Q. What are the dimensions of the middle Neebish now?

A. That scales about 400 feet. I have not personally seen the middle Neebish, nor been very familiar with it since 1898.

Q. The depth of water through that Channel is what?

A. Twenty-two feet is indicated here.

Q. You testified, I believe, on direct examination as to the slope of the St. Marys River?

A. Yes.

Q. The slope from the foot of the locks to Lake Huron is about how much now?

A. Something over a foot. I said our elevations were not sufficient to accurately determine that; at least I have not personally looked into the matter.

Q. Do you know or have you available records from which you can ascertain what the change in that slope has been during the past twenty years, say since 1888?

A. From 1886 to 1890, the mean slope between the water at the foot of the locks and the Harbor Beach gauge is 1.99 feet, practically two feet. From 1891 to 1895, 2.40, 2.4 feet. From 1896 to 1900, 2.74 feet. 1901 to 1905, 2.14. Now that slope is in a measure, dependent on the amount of water going through the river; that has some effect on it, a lowering of stage of Lake Huron, as we stated in our back water effects, before.

Q. Was there any record prior to 1886?

A. Yes, they reach back to 1871, to 1875. That was prior to the improvements though there.

Q. Suppose we have them from 1871 down, if you have them conveniently before you?

A. Very well; 1871 to 1875—these are five-year periods—3.03; 1876 to 1880, 2.30; 1881 to 1885, 2.07; 1886 to 1890 you already have as 1.99.

Q. Now from 1905 to date, your information, you say, is not entirely accurate?

A. No, this is from a report dated 1906. I have not brought that up to date.

Q. Can you briefly indicate the improvements that were made these several periods, which caused the variation, or had a tendency to cause the variation in the slope. For instance from 1875 to 1880, there was a difference of about 7/10 of a foot in the slope. Was there any improvement constructed there at that time that might have had the effect of reducing the slope to that extent?

A. I know of none.

Q. Are there any of the variations in slope indicated by the figures that you have given that you would say in your opinion were attributable to any improvements constructed in the St. Marys River?

A. Perhaps I can get at what you are after by one single statement.

Q. That is what I would like?

A. I think it is very probable that the water has been low-

ered a foot at the locks by reason of improvements in the river.

Q. That is the several improvements?

A. Yes. At the Middle Neebish, there was some compensation; a dam was run through the shallow water, but I think the compensation was incomplete, and yet I speak without full knowledge of the hydraulics of that lower river. A compensation I think at Little Rapids was attempted also. I do not know to what extent it was effective.

Q. Has the effect which you have indicated as resulting from these improvements resulted in the lowering of the water over the mitre sills of the Poe lock?

A. Yes.

Q. To the same extent as you have indicated?

A. I should say a foot, yes. I will state that as strong as you like

Q. And that lowering would have the same effect upon navigation as the lowering caused by diversion at Chicago, which would be sufficient to lower the level of Lake Huron a foot, would it not?

A. I see no difference.

Mr. Wilkerson: You refer to that as in the St. Marys River; not over the lower lakes?

A. I refer to it simply on the floor of the Poe lock.

Q. Not over the lower lakes?

Mr. Williams: No, we do not understand it that way.

The Witness: In that particular case the alternative of introducing very swift current or accepting a lowering at the locks was presented, and the lowering at the locks, in view of a new lock, was considered the lesser evil.

Mr. Wilkerson: It was a choice between evils was it?

A. Yes.

Mr. Williams: What is the tendency of the several improvements now under way and in contemplation by the government, as to the lowering of the level of the upper lakes?

A. By the upper lakes you mean Michigan and Huron?

Q. All the lakes above where the improvement is either being made or contemplated?

A. You mean the effect on Lake Superior?

Q. Not the lake itself, but the effect upon the St. Marys River up to the foot of the locks, and the other lakes above where the improvement is being carried on. In other words, what I am getting at is: Isn't it the tendency of all the government improvements to lower the level of the lakes lying

above the point where the improvement is being made, and reducing the slopes?

A. I should say not.

Q. Are you familiar with the work done by the government in dredging at the foot of Lake Huron during the years, 1889, 1891, 1892?

A. Not in detail.

Q. You are familiar with the fact that that work has been done?

A. Dredging has been done there, yes.

Q. Do you know what the tendency of that work has been upon the level of Lake Huron?

A. No.

Q. Do you know whether it had any effect?

A. No.

Q. You are familiar with the fact that dredging was done by the United States government in Lake St. Clair, during the years, 1893, 1894 and 1895?

A. I know dredging has been done, but not in detail.

Q. Do you know whether that work had any effect upon the level of the St. Clair River, and Lake Huron?

A. I do not know.

Q. Or either of them?

A. I do not know as regards amount; I should say a trivial effect would enter.

Q. There would be a tendency for it, would there not?

A. I should think so, yes; a small tendency to lower.

Q. Well, now, going back to the other question, wouldn't the tendency be in all improvements of this character to lower the level of the bodies of water lying above the point where the improvement was being carried on?

A. I should say the tendency would be on the side of the lowering rather than on the other side, but it is very small aside from the one case that I have testified about, regarding the water over the floor of the Poe lock. The tendency in creating channels has been to make a bigger opening, and a deposition of material elsewhere has tended to make a smaller opening there, and there has been compensation to a considerable extent; and that whole question of the lowering has to be taken altogether.

Mr. Wilkerson: These last dredgings you are speaking of now, do you know just where they have been made?

A. In Lake St. Clair?

Q. Yes.

A. In the neighborhood of the Flats and also at the foot of Lake St. Clair.

Q. Are those critical points?

A. Yes.

Mr. Williams: Assume that there was a natural channel 2,000 feet in width, with ten feet of water at the deepest point, having a slope of one foot in 10,000; the entire channel having a cross sectional area of 12,000 square feet. Then assume that the central portion of the channel was dredged to 20 feet in depth with a width of 240 feet, the excavated material deposited in the shallow portions so that when the improvement is completed the new channel has exactly the same cross sectional area as the original natural channel. What would you say as to the amount of water that would flow through the new channel as compared with the old, assuming that there has been no change in the slope. Mr. Williams has given you a diagram or sketch of the two channels such as are embodied in my question.

A. If I comprehend this question right, an approximate answer to this is that the amount of water would vary as the square root of 20 to the square root of 10. That is not accurate; it is simply an approximation.

Q. What I wanted to get was would the amount of water be increased or decreased?

A. For the same slope in the compact section, as compared with the shallow one?

Q. Yes.

A. The water would be increased, the amount of flow would be increased.

Q. Then if in a shallow channel a deep channel is constructed and the only compensation attempted is to deposit the excavated material in the shallow parts, so that the cross sectional area was not in any way decreased, the amount of water flowing through the new channel would be increased, assuming the same slope?

A. Yes, there would be more water, considerably more through the compact channel. That statement that it would be in the proportion of the square root of 20 to the square root of 10 was very approximate. It would be the square roots of the hydraulic radii.

Q. Your approximate answer would indicate an increase of about 40 per cent in the amount of water flowing through the same sectional area?

A. I think perhaps it would be a little less than that. There

would be decidedly more water under those circumstances; if the compensation was one square foot per square foot of cross sectional area, it would not compensate it.

Mr. Wilkerson: If they piled this up, so that they made the cross sectional area less, you mean?

A. I testified in the Detroit River the intention was to make compensation by making the area less. That is considered in the plans for compensation in the lower Detroit River.

Q. That in deepening, the cross sectional area is to be diminished?

A. To get an effective compensation.

Q. And that is done by piling up the excavated material in a way which diminishes the size of the cross section?

A. Cuts off part of the cross section that compensates the new cut, by that additional 40 per cent, or whatever may be needed to take care of it.

Mr. Williams: Assume in the previous hypothetical question that everything was filled in except the artificial channel, 300 feet at the top and 240 feet at the bottom, all the shallow part was filled so that the cross sectional area of the new channel would be considerably less than the total cross sectional area of the original channel. What would you say in that case as to the amount of water that would flow through the new channel as compared with the old, assuming the same slope?

A. Without careful computations, I would not care to give an answer to that question. The general proposition that in compensating you need to cut off more area of shallow water than the increased area in a compact section is well established; there is no question about that. And in discussing the working up of the method of this compensation in the lower Detroit River, that is taken into consideration; the form of the section, as to whether it was compact, and the form of the shallower section which has to be cut off to compensate it.

Q. In order to render the compensation complete, the cross sectional area in the new channel in the Detroit River will be less than the cross sectional area of the river at that point?

A. Yes.

Q. I will ask you, after having propounded this hypothetical question to you, whether or not the case presented by the question that I asked you does not fairly illustrate the con-

ditions of the connecting waters of the great lakes as they stand, without the improvements? In other words, isn't the problem which I have suggested a fair statement of the situation as it exists?

A. No, for the reason that other matters have come in that enter into the case. I have discussed them somewhat in my report on the preservation of Niagara Falls, on the Niagara River there. And there the narrowing of the river in places, the extension of docks out from the original shore line has a tendency to cut off part of the cross sectional area. At Tonawanda on the Niagara River, for instance, an encroachment has been made; dredged material is as a rule dumped in the river itself and has a compensating effect. In the Detroit River for instance, the advance of the dock line has narrowed the river along the Detroit front; and it is true on the Canadian side as well; and the tendency is encroachment, in a good many cases they compensate.

Q. But you cannot any more than fill up the shallow parts of the river with this excavated material?

A. There is no excavated material opposite Detroit, but the dock line has been advanced and cut off the river.

Q. The docks cannot extend further than the line of navigation?

A. The harbor line is the limit of the docks; that is established by the War Department. I might say that on Lake Ontario an improvement, if it may be considered such, the Gut dam, to which our government consented and is therefore a party to, raised the elevation of the St. Lawrence River and Lake Ontario four to five inches, as I have previously testified.

Q. ,What was the amount of head figured by you in estimating the water power at Niagara, at these power plants?

A. 220 feet; that is at the cataract and the rapids above the cataract.

Q. And you figured the entire fall from what point?

A. From the intake of the Niagara Falls Power Company to the portal, which is the outlet of the same company.

Q. Are there any losses in the head or in the tail race?

A. I took account of those in the 80 per cent. I made a reduction of 20 per cent for loss.

Q. You mean that your estimate of 25-horse power per cubic foot was theoretical horse power?

A. Theoretical, on the head of 220 feet. It is 220 divided by 8.8.

Q. And then your loss of 20 per cent in the actual is what you allowed for the loss in head and tail races?

A. Yes.

Q. What degree of efficiency do you figure then in the wheels?

A. Perhaps 84 or 85. For those wheels on the high heads, I understand the efficiency is very high. Higher than the ordinary turbines.

Q. 84 or 85, if you allowed for efficiency 85 per cent, that would only leave 5 per cent that would have been lost by reason of head and tail races?

A. That is something over ten feet; the actual head under which the Niagara Falls Hydraulic Company is operating is about 210 feet. That is between head water and tail water.

Q. Is this head you are testifying about on the American or Canadian side?

A. That is on the American side.

Q. You were asked by Mr. Wilkerson with reference to diversions at Niagara, and the effect of those diversions, if any, upon the level of Lake Erie. What diversions did you have in mind?

A. The diversions of the Niagara Falls Power Company; the Niagara Falls Hydraulic Power & Manufacturing Company, and the Ontario Company on the Canadian side.

Q. How many cubic feet per second would you say is involved in those relations?

A. Something less than 20,000.

Q. 220,000 cubic feet per second?

A. Per second, yes; that is there is not that much in use at the present time. Perhaps 15,000 cubic feet per second would be a closer estimate.

Q. Now what were the compensating influences that caused those diversions to fail to influence the level?

A. Why I should state in this connection that our earlier measurements of the river were made in 1898, when about half the present diversion of the Niagara Falls Power Company was in effect, and the added diversions since that time—I am speaking very roundly now—may be eight or ten thousand cubic feet per second. I think perhaps I have not stated that correctly. The effect of a diversion of about 11,000 cubic feet above the rapids there would lower Lake Erie about half an inch, 5/100, and during certain years, 1904 and 1905, the divertors of the Ontario Company were in place, and those backed the river up, so that there was a rise of something

like four inches in the river above the rapids there at Niagara Falls, and that would temporarily give Lake Erie a tendency to rise, but the rise would be very small; it would be 3/16 of four inches.

WILLIAM LIVINGSTON, a witness recalled for further cross-examination by Mr. Williams, testified as follows:

Q. Mr. Livingston, one of the questions that was asked you, which you said you would look up was with reference to the percentage of boats that would be affected by a diminution of draft of two inches, boats that ply in the northern lakes, and in the harbors of Lake Michigan, that do not pass through the St. Clair and Detroit Rivers?

A. That do not pass through?

Q. Yes.

A. I cannot give it to you. I have sent for the information but I have not obtained it. I want with your permission to correct one statement I made the last time I was in. I said that the average cost per day for the running expenses of a boat was $160. That of course was exclusive of loading and unloading; I am just talking about the operating expenses of a boat independent of that. It would be $160 a day including insurance. I started to get these matters in motion and I had to send over to get some data that I didn't have in the office, and I got to figuring over and looking over some statements which I have, and I would like to correct that. I think I made that too low; I think I should have made that $180 a day. I find there are two or three things I neglected to take into consideration. We always increase the wages of our employes, for instance, the first of October, increase them ten dollars and so on, depending on the positions they are in. And there are a number of other matters, and I find a difference too in many of our fleets in the way of computing expenses; the system of bookkeeping is a little different, so I am satisfied now, after spending a little time, that for that class of boats, 10,000 tons, I should have said $180 a day to have been safe. I would like to correct that. Ordinary maintenance and upkeep such as painting and minor repairs are included in the $180 per day; that also covers insurance.

Detroit, Michigan, June 4, 1909, 10 A. M.

Parties met pursuant to notice.

F. C. SHENEHON, resumed the stand for further cross-examination by Mr. Williams and testified as follows:

Q. You have charge, Mr. Shenehon, of the publication of charts showing the channels through the Great Lakes and connecting waters?

A. The Lake Survey issues those charts.

Q. And they are under your direction?

A. Under the direction of the officer of the Lake Survey. I understand you mean finished charts that were published?

Q. Yes.

A. The Principal Civilian Engineer, which is my title, has more direct charge of the field process, although as First Assistant to the officer in charge, he has an indirect charge of the whole office. But my supervision over the actual publication of the charts is rather small.

Q. Can you furnish us charts from which can be obtained cross sections of the Detroit River at the Lime Kiln Crossing?

A. The chart of the Detroit River will give that, but not with a high degree of precision.

Q. Within what degree of precision would you say the chart would give that cross section of area?

A. I should say within 5 per cent.

Q. Have you one of those charts available?

(Witness produced a chart which was marked for identification "Defendant's Exhibit A, June 4, 1909"; the same being a chart of the Detroit River projected from a trigonometrical survey issued under the direction of Major C. B. Comstock, of the Corps of Engineers, Brigadier General U. S. A., in 1873. Additions and corrections under the direction of Major W. L. Fisk, Corps of Engineers, U. S. Army, in 1902-4, and Colonel G. J. Lydecker, Corps of Engineers U. S. Army, 1905-6, and Major Charles Keller, Corps of Engineers, 1907-9.)

The Witness: I should like to change that precision to 10 per cent. I figured on about one foot of allowance there, and I see there is only about ten feet of water in place; 5 to 10 per cent, make that.

Q. Would you say that it was precise within one foot; that was the basis of the estimate?

A. Yes, I should say it was closer than that.

Q. By referring to that chart, can you readily give us the original depth along the section of the Detroit River in the Lime Kiln, or if you have other sources of information from which you can give the information, let us have them.

A. This shows the condition of the river on March 20, 1909, not in its original condition.

Q. Do you know, Mr. Shenehon, what the depth originally was along that section?

A. No, I do not.

Q. Can you state what the widths and depths of the channels through that section are, at the present time?

Mr. Wilkerson: You mean the dimensions before any improvements were made at all?

Mr. Williams: That was the other question, but he says he cannot give that. Now I ask for the width and depth of the present channel.

A. The width of channel given is scaled from the chart and shows for the Lime Kiln 600 feet.

Q. Six hundred feet in width?

A. Six hundred feet in width, yes; with a depth of twenty-one feet when Lake Erie is at elevation 571, by the levels of 1903.

Q. Have you in your custody or in your office surveys or charts or any other sources of information from which you could give us the original depth of the channel at that point?

A. I think so. I will have to have them looked up.

Q. What is the total width of the river at that point, the width of that section rather?

A. About 8600 feet.

Q. Is there a current over the entire width?

A. I think so.

Mr. Wilkerson: You are now speaking of the Lime Kiln crossing?

Mr. Williams: Yes, the section of the Detroit River at that point.

Q. Does Stony Island have any effect upon the current in that section?

A. Stony Island is above the section I measured, and in the wake of Stony Island, below Stony Island there should be dead water for a certain distance.

Q. At the point where you measured, you will say there is a current across the entire channel?

A. The section measured is about 2100 feet below Stony Island, and I should say there was current in every portion of that.

Q. In giving your answer as to the width of the present channels, 600 feet, did you include the Livingstone channel in that statement?

A. No.

Q. I believe you testified to it before, but so that we can get it all together, will you now state the dimensions of the Livingstone channel now in course of construction?

A. Three hundred feet in width at that point of the river, and 22 feet deep below Lake Erie elevation 571.

Q. Can you give the dimensions of the channels that are cut off by the cofferdam, which is shown on the chart?

A. The cofferdam from the east point of Stony Island extends eastward about 1400 feet, and the completed portion extends down stream about half a mile. The old pier of the Michigan Central Railroad, which coincides with the upper end of the cofferdam, had an original length of 1200 feet.

Q. What is the width of the channel at the upper end of the cofferdam; the entire river? The cofferdam is not situated at the point where you made the measurements of a few moments ago?

A. No, about 3200 feet above the section measured.

Q. At that point its width is what?

A. At that point the river width is about 3500 feet east of Stony Island and 1100 feet west of Stony Island.

Q. Can you give us the depth of water along the upper end of the cofferdam?

A. From five to fifteen feet.

Q. That is shown on the chart?

A. The nearest soundings indicated are five, six, ten and fifteen.

Q. What is the most accurate method of measuring water, Mr. Shenehon?

A. Such rivers as we have under consideration, the current meter method.

Q. Without reference to the rivers we have under consideration, what would you say was the most accurate method of measuring water? Isn't it by weight, the most accurate method?

A. By weight, yes.

Q. And next to that what would you say was the most accurate?

A. By volume, the size of the vessel containing it.

Q. And the next to that?

A. Current meters.

Q. What would you say as to the degree of accuracy that may be reached in the measuring of water by means of a weir as compared with current meters?

A. I should say the current meter method is as accurate.

Q. Is as accurate?

A. Is as accurate, yes.

Q. Would you say it was more accurate?

A. Very inaccurate work can be done with a weir.

Q. Assume the same degree of skill exercised in measuring with a weir as would be exercised in measuring with a current meter?

A. I am not familiar with weir measurements by having made any personally. I have a very general knowledge of the subject, and the exact degree of precision I am not prepared to state.

Q. In making your gaugings with a meter, you seek to get the meter in the same vertical section at each gauging?

A. That is at the same station, as we call it; it is the same vertical line; when I say the same, within a few feet of the same.

Q. You make an effort to get it as near the same as possible?

A. Within the limits we regard as required by the accuracy, yes.

Q. How close would you say you are able to do it?

A Oh, four or five feet, or less.

Q. Are the velocities in a flowing stream uniform from one point to another?

A. No. Let me understand what you mean. You mean do they vary in uniformity from one point to another by regular gradations. What is the meaning of your question?

Q. I mean are they uniform; is there any law so that you can tell from the gauging at one point exactly what the velocity is at another point some feet distant from that?

A. Taking a station well out in the stream, of one of the sections that we have used in the Lake Survey measurements, the velocity four or five feet away from a particular station is very well known; the variation is sufficiently uniform so that we do know.

Q. Is it absolutely uniform?

A. I should say not.

Q. It would be practically impossible, would it not, to observe the velocity of a stream at every point?

A. Yes.

Q. Assume a circular pipe of a uniform diameter, and flowing water through it, what would you say as to the uniformity of flow through a river as compared with the uniformity of flow through that kind of a channel, opening?

A. I should say the uniformity through the river was very much higher, through such sections as we have used in our gauging.

Q. I call your attention, Mr. Shenehon, to page 5369 of Appendices III and KKK of the Annual Report of the Chief of Engineers for 1900, and particularly to this sentence appearing in the middle of the page: "The fluctuations in current velocity have usually rendered the determination of the distribution of the velocities in the vertical plane a difficult matter, for if the meter were left at one depth long enough to eliminate the effect of the short, wave-like fluctuations or pulsations of the current, a more permanent change might take place affecting the mean velocity at the station before all of the depths had been covered by the meter." Do you endorse that statement?

Mr. Wilkerson: This is from Mr. Sabin's report.

A. As I understand that statement, Mr. Sabin has reference to the older method of current meter measurements, in which you used a single meter; getting your vertical curve by starting at the surface, or a short distance below it and observing a certain definite time at each tenth of depth. The use of the multiple set, of which Mr. Sabin speaks, and the use of the two meter system that I have used myself, is intended to eliminate all possible sources of error or difficulties of which Mr. Sabin speaks. The water does come in pulsations to some small extent, and the more permanent change he speaks of, I take to mean a change coming with change of gauge.

Mr. Wilkerson: Did you read that sentence about the overcoming of the difficulty? I wish you would read that sentence so that we will have it all in the record.

Mr. Williams: The latter part of the sentence is as follows: "This difficulty is overcome by the use of the multiple meter set, with which the whole vertical curve is determined at one observation."

Mr. Wilkerson: That is the explanation that you referred to in your answer, is it?

A. Yes.

Mr. Williams: You endorse the statement then?

A. I state that the velocities in a river at a given point are fluctuating from minute to minute, and that a change of velocity does come with a change in the lake stage.

Q. And also that there may be certain pulsations that are not permanent in their character and not depending on lake stage, is that true?

A. Yes, if two observations were made, covering ten seconds, they would not closely agree.

Q. And the advantage of having this multiple meter set, which is mentioned in this paragraph, is in effect that the measurement is made at the several points simultaneously, so that anything that affects the meter at a given point would affect all the others at the same time?

A. That is the intention of the multiple meter set, yes.

Q. If that is an advantageous arrangement in the measurement of current velocity, what would you say as to the necessity for some arrangement being made by which the same degree of precision could be obtained by having horizontal measurements made simultaneously?

A. I think the gain to be made by the multiple meter set is one of time-saving rather than ultimate precision. I think just as high precision is gotten by two meters, as I myself have used them on the Niagara River and the St. Lawrence River.

Q. The purport of this report is that the multiple meter set was used for the purpose of curing the inaccuracies that might result from allowing the meter to be left at one depth long enough to eliminate these temporary effects, was it not?

A. The temporary effects that you speak of *are* temporary. The average relation in velocity between two points is fixed very decidedly. The only point is, how are you going to establish that relation, whether simultaneously by multiple meter sets, consisting of a number of meters, by two meters, or by a single meter that by a great many repetitions gets the average percentage relations in the curve. The *facility* of the operation is involved in the use of either two meters or a multiple meter set.

Q. And is not the accuracy of the observations also involved?

A. I do not think the accuracy obtained by the multiple

meter set is greater than the accuracy obtained by two meters.

Q. Is it greater than that obtained by one meter?

A. I think so, although a very large number of observations in the vertical with a single meter does give good results.

Q. Over what percentage of the area of a cross-section is the velocity actually measured in gauging?

A. Perhaps over 25 per cent.

Q. The same observation?

A. Perhaps I misunderstand your question.

Q. With a single gauging, you say that 25 per cent. of the entire area of the cross-section is actually measured.

A. I do not get the trend of your question. I do not know what you are getting at.

Q. Take the area of the cross-section occupied by the meter during a single observation on the St. Clair River.

A. That is a single discharge measurement?

Q. Single gauging?

A. Yes.

Q. The wheel has a certain diameter, and a certain area, hasn't it?

A. Yes.

Q. You observe at a certain number of points a single gauging?

A. Yes.

Q. Now what is the percentage of the actual cross-sectional area of a river covered by any single gauging; take the St. Clair River, for instance, as an illustration?

A. I should say about one-sixtieth of one per cent.

Q. I call your attention to Plate 12, following page 5400 of the report of the Chief of Engineers for 1900, Appendices III and KKK.

Mr. Wilkerson: Is it Plate 12 in connection with Mr. Sabin's report?

Mr. Williams: Yes.

Q. Will you explain that plate? Tell us just exactly what it means?

A. Figure I of this plate is a cross-section of the St. Clair River at Section Dry Dock, showing the bottom profile of the river, the water surface, of current meter stations 1 to 21; and velocities at or near percentage depths; that is close to the surface, close to the bottom and at each of the tenths of depth. These velocities are established by twelve discharge measurements, Nos. 49 to 60 inclusive. Using these velocities, contour

lines are drawn in, which are intended to show the lines of equal velocities.

Q. Each of the lines shown upon Figure I indicates a certain degree of velocity?

A. Commencing with the line at Station 6, that shows the location of the velocities having 3.4 feet per second. The next one to the right shows 3.6; the next one 3.8; the next one 4.0; the next one 4.2; and the small figure under Stations 13 and 14, 4.4. The lines to the left of Station 6, one line is the mean velocity that is a little heavier line than the others. And I think the lines differ by changes of .2 of a foot per second beyond.

Q. These stations numbered from 1 to 21 are a hundred feet apart?

A. I believe so. I should state in connection with this plate that it is my belief that it is the intention to give the velocities only in a general way, to show the distribution over the section; that the precision of the thing as it stands is not very high. It is made up from twelve discharges only.

Q. What degree of precision would you give this plate?

A. I could not make any statement on that point.

Q. What degree of precision would you say it would be possible to get in the drawing of a plate of this character?

A. What do you mean by precision?

Q. How accurately would it be possible to have a plate prepared, so that the lines drawn on it would represent the actual situation as to velocities?

A. Very close to one per cent.; and when I say that, I mean that instead of velocities being set down, the percentage relations of the velocities be set down The velocities indicated there are for twelve discharges.

Q. How many discharges would you say it would be necessary to have in order to prepare a plate to be of the accuracy that you have indicated?

A. The precision would depend more upon the co-efficient work than upon the discharge measurements.

Q. Then you would say that twelve observations would be sufficient?

A. I should say that twelve determinations of percentage relation between the index and any other point would give a very good determination of it.

Q. Will you explain what you mean by co-efficient work?

A. Co-efficient work is to establish the percentage relation between the velocity which measures by the meter at the sta-

tion index, (a particular depth as .3 or .4 depth in the river) and the velocities at other points. The object of co-efficient work is to establish a multiplier or co-efficient by which the velocity at the *index,* at a single station, is multiplied to get the mean velocity in that station. When I say "station" in the second case I mean in that 100-foot width of the river.

Q. Can you explain a little more in detail how you arrive at this multiplier that you have just mentioned? The actual observations occupied, as you say, about one-sixtieth of one per cent. of the entire area of the river being measured, cross-sectional area. How do you arrive at the velocities at the other points?

A. The process of river measurement is a sampling process. When I speak of the measurements in a river occupying a sixtieth of one per cent., I mean samples of the velocity taken cover that part of the area. A bridge engineer in building a steel bridge, I do not imagine takes more samples than one-sixtieth of one per cent. of the weight of the structure; probably less. Sampling of various kind, for wheat, and other things, I do not imagine takes more material.

Q. When you take that much of the material, what do you know about the rest?

A. When you take the measurement in the river, you know by a great many observations in support of that knowledge that the percentage relations is obtained. I will read certain testimony on that line if it is desirable.

Mr. Wilkerson: That is, you have a statement that will explain that.

The Witness: Showing the relations.

Mr. Wilkerson: Do you want that?

Mr. Williams: We are entirely willing. We want all the information we can obtain.

Mr. Wilkerson: I suggest if he has it in well worked out form, it would be perhaps better than the off-hand statement.

Mr. Williams: Now you may proceed. Give us the reference.

A. This is in the report of the Chief of Engineers for 1900, page 5343, and begins: "It has been demonstrated in river hydraulics that the velocities throughout a certain area maintain definite percentage relations, and when these relations are firmly established by ample observations, a single known velocity is the key to all others simultaneously existing, and hence to the discharge in the area involved. On this characteristic of river flow are based the methods used to determine the

volume of water which the river carries in its various stages and conditions. Like most hydraulic laws, this has its limitations and is more nearly absolute as the area considered approaches an element of river width. How accurate it is for the full river width is shown by the following tabulation, in which the mean velocities for each station derived from groups of discharge measurements are expressed as percentages of the mean velocity of all stations for the same group." And the table which follows is headed: "Open Section, Table 5, index velocities as percentages of mean index velocity. Now in this table, the velocities shown by groups—

Mr. Wilkerson: Q. What you have said heretofore is quoted?

A. Yes.

Q. Now you are testifying.

A. Yes, I am just talking. In this table the velocities shown by groups of *ten* discharge measurements are expressed for each station in the form of percentages of the mean index velocity, except that group No. 6, has *seven* discharge measurements in it. As an illustration of the precision with which the percentage relation is maintained, I take at random Station 9. The first group shows the velocity there to have a percentage of 118.2 of the mean velocity; the second group 121.1; the third group 120.5; the fourth group 121.4; the fifth group 121.6; the sixth group 122.1; and the mean of the whole is 120.7.

Mr. Williams: Q. Take Station 1, Mr. Shenehon.

A. Station 1 has a large variation and cuts very little figure in the discharge of the river. I took Section 9 because that carries a high percentage of the flow, and for a second reason because the mid river stations are less variable than those close to the shore.

Mr. Wilkerson: One is a station that is near the shore is it?

A. Yes, that is close to shore.

Q. How far from the shore?

A. Where the area change is fairly large at different lake stages.

Q. Just what percentage of the total flow passes through one?

A. It is less than one per cent., as I recollect it.

Mr. Williams: Q. Will you take Section 8, Mr. Shenehon, as shown by that table, that index?

A. Station 8 shows for the first group 121.3; second, 122.9;

third 124.6; fourth 124.9; fifth 124.5; sixth 123.3; mean 123.6.

Q. Will you look at plate No. 7, following page 5360 of the report of the Chief of Engineers for 1900 and explain the curve shown on that plate for Station 8?

Mr. Wilkerson: The cross-examination of the witness is, I assume, proceeding on the theory that the plates and protions of the reports referred to will be afterwards put in evidence by the defendant. That is correct, is it not?

Mr. Williams: Yes. We now ask to have this Plate No. 7 marked for identification as "Defendant's Exhibit C, June 4, 1909, cross-examination of Mr. Shenehon." Plate 12, following page 5400 of report of 1900 will be identified as "Defendant's Exhibit B, Shenehon's cross-examination."

Q. (Last question read as follows: "Will you look at Plate No. 7, following page 5360 of the report of the Chief of Engineers for 1900 and explain the curve shown on that plate for Station 8.")

A. Station 8 is marked at the bottom of the curve I am explaining. This shows the velocity at that particular station on the Open Section of the Niagara River, or rather the percentage velocity with respect to the velocity at the *index,* which is always 100 per cent. These percentage velocities are platted on the horizontal scale (in a system of rectangular co-ordinates), and the river depths expressed in elevations are shown in the vertical scale. Using this series of heights above the bottom, or elevations, and the percentage velocities, the observations are platted, as shown along the curved line. Those that are platted in solid black circles at the *sub-surface,* the index and the .8 depth and the bottom observations (except for the index always 100), were derived from discharge measurements in addition to the other co-efficient work. That is in measuring a discharge of the river, a current meter was run at the index depth, which is 4/10, roundly, of the river depth at a particular station. The second meter is run at the sub-surface for two minutes, then the second meter is dropped down alongside of the index meter and run for two minutes more. Then it is dropped down to the .8 depth and run for two minutes more, and on a part of the observations it is run down to what is called the bottom observation and run for two minutes more. So each discharge observation, in addition to giving the absolute velocity at the index gives also the percentage relations from surface to bottom throughout the vertical. And as I have already testified, the velocity relationship betwen the stations gives the trans-

verse curve. The observations shown by open circles were derived from special observations, made specifically as co-efficient work. After platting these observations, the curved line is drawn in as a fair line, and it is made to thread, or pass through, the sub-surface, index, .8 and bottom observation.

Q. In doing that, there are a number of points that were determined by several observations that are not touched by the curved line.

A. It is assumed that the law of gravitation under which the river is flowing will be expressed by a fair curve, for the vertical curve; and where we have but two observations as at elevation 547, to pass the curve through that would make a wavering line instead of a fair curve. The weight of the two observations does not warrant that. I wish to say, however, that if a line were drawn that did thread every observation in that curve and that of Station 6 on the same plate, that the results so far as the river discharge is concerned, would be the same; there would be no sustantial change.

Q. But as a matter of fact the observations at point 547, 545, 542, 537, were practically not considered in the drawing of the line?

A. The line was drawn for the most part so as to thread the obseravtions. When I say that, for instance take the observation at 545 and that at 547, the line is drawn between them. And the line cuts a point that might be a mean between those observations, in elevation as well as in velocity, percentage of velocity.

Q. As a matter of fact the line could just as well have been drawn from these index points to .8 depth, from that point on to bottom observation, without any reference to the observations of the points mentioned?

A. No, that is not so.

Q. Suppose that observations at 547, 545 and 542 were all eliminated from consideration; that you were drawing a curve that would pass through the observation of the sub-surface, the index, at .8 depth and bottom, what difference would there be in the shape of the curve?

A. That was 537, was it, Mr. Williams?

Q. Leave out 537, 542; the points determined by four observations there. Leave out 545, the point determined by six observations and 547, the point determined by two observations, eliminate all those, what would be the difference if any in the direction of the line? Eliminate everything between the index and the bottom observation.

A. The observations at 545 and at 547 have been given weight in drawing the line. You notice the line hugs the observation of 6 rather than it does the 2; perhaps I ought to reverse that and say the observation hugs the line a little more closely; the six observations having greater weight, it brings it closer to the line. The observation at 542 and that at 537 do not seem to have swerved the line largely.

Q. If the line passes through the observation at point 543, which is determined by six observations, and passes through the index point and the .8 depth point, how could you very well vary the direction of the line, even eliminating the points at 545 and 547?

A. Whether the observations at 545 and 547 were present or absent makes very little difference in the trend of the line at that point. The observations are confirmatory of the general trend of the line, as they stand.

Q. Would it not be a fairer indication of the actual result of the observation to have drawn your line so as to pass through the point determined at 545 as the result of six observations than to pass by that point and to pass through the points at 548 and 552, which were the result of only two observations each?

A. The object of drawing the line ought to be very clearly kept in mind. We are endeavoring to get the mean percentage velocity ordinate, and whether or not we draw a mean line between two observations or whether we waver the line and thread the particular observations, the result is the same substantially.

Q. Would your contour lines on a map or plate showing the cross sectional area be the same if the line were drawn through point 545 as it is drawn in the direction in which we find it? Wouldn't that make a difference in our contour chart?

A. If the line which we call the vertical curve were drawn so as to pass through 6 at 543 and also through the 6 at 545; through the 2 at 547, joining the line at the 2 at 549 again, the mean ordinate, which is what we are after, would be substantially the same. There would be substantially no effect on the discharge of the river.

Q. Now there is a variation in the velocity of this particular Station 8 within distances of two and three feet, isn't there?

A. In the vertical?

Q. Yes.

A. Very distinct towards the bottom, yes.

Q. That being true, what means of information have you, what knowledge have you as to what the variation may be between this vertical and the next one which is a hundred feet distant?

A. The general form taken by the vertical curve is such that we feel full confidence in view of the corroboration of results and extended river experience, that in midstream we may safely extend the coefficient.

Q. A distance of a hundred feet?

A. For a distance of 50 feet each side of our section. To illustrate that, let me look up the coefficients. I do not find that the coefficients are given for the Open Section, but for the St. Lawrence beginning with Station 4, we have a coefficiency of—

Q. What is the reference there?

A. This is the report of 1902, page 2803. This is my report on the St. Lawrence River, and I am reading from Table No. 19; beginning with Station 1, 88.8 per cent; Station 2, 90.8; Station 3, 88.5; Station 4, 85.6; Station 5, 87.7; Station 6, 89.5; Station 7, 90.7; Station 8, 94.8; Station 9, 94.1; Station 10, 92; Station 11, 92.2; Station 12, 90.5; Station 13, 89.9; Station 14, 92; Station 15, 92.7; Station 16, 91; Station 17, 92.7. The weighted mean is 89.8. Now, if these vertical coefficients, which represent the mean ordinate of this curve, if they vary very slightly from one station to another, even though they form a curve which is slightly different, the result would be no different in the volume of discharge. After a very considerable experience in river measurements, I have the utmost confidence in the continuity of changes of velocity in a river.

Q. And in their uniformity?

A. And in the uniformity, where we would expect it, as in midstream, or in the open part of an open river. Towards shore we do get eccentric conditions, but these by extra observations are considered. The shore end stations of a discharge section in a river carry but one to two per cent ordinarily of the volume of flow; and if in these stations we have an error as large as 10 per cent, the error of the whole volume of the discharge is only one to two-tenths of one per cent, which is insignificant. The big volume of flow is carried in the mid-river sections.

Q. You have finished your answer, have you?

A. I have found something I was looking for; that is the

mean velocity coefficients in the Open Section, that perhaps I had better read, as more pertinent than those in the St. Lawrence previously quoted.

Q. The reference is what?

A. This is page 5347 of the report of 1900. It is a tabulation headed "Open Section, Mean Velocity Coefficients." The depth on Station 1 of the Open Section is so small that velocity coefficients in the vertical are not given. I will give these for elevation 567: Station 2 is 92.8; Station 3, 92; Station 4, 92.5; Station 5, 92.6; Station 6, 92.6; Station 7, 92.6; Station 8, 93.2; Station 9, 92; Station 10, 89.9; Station 11, 89.5; Station 12, 91.2; Station 13, 92.9; Station 14, 91.2; Station 15, 90.6; Station 16, 91.1; Station 17, which is in extremely shallow water and which does not give a fair value for the coefficient is 84.8. That last explanation is not quite correct; I should have stated that for Station 17 it includes the transverse coefficient as well as the depth of water. These are the *mean velocity coefficients* including transverse as well as vertical. An examination of the coefficients derived by Sabin for the St. Clair River will show very close corroborations of these.

Q. I understand that these are the factors by which you multiply the velocity found at the index point?

A. Yes, multiply the velocity shown by a discharge measurement at the index point by the mean velocity coefficient, and that by the cross sectional area; that gives the discharge.

Q. And your judgment is that the mean velocity shown at the index point on one vertical and the velocity shown at the index point on another vertical a hundred feet distant indicates the velocity for the entire 100 feet between the two?

A. No, that is not quite accurate.

Q. Well, state what the fact is with reference to that?

A. From the shore out as far as the indications warrant, a transverse curve is taken; that is the velocity is taken every ten feet, and the relation of the velocity to that the index point for the .4 depth, every 10 feet is taken. As soon as the open river is reached, where the sweep of the transverse curve is broad, these observations are not always taken. I believe they always were in the St. Clair River, but not in the St. Lawrence, and not in the Open Section of the Niagara River. The transverse curve is taken from the fair curve line joining the velocities at the index, as derived from the discharge measurements. That will show you a number of percentages,

showing the relation. Then platting those and drawing a line through them gives the transverse curve.

Q. As a matter of fact you have no information as to the velocities between your verticals except such as you get by the drawing of the transverse curve?

A. That is true in the Open Section of the Niagara River, except towards the end, towards the shore—

Q. Towards the shore ends?

A. And the same in the St. Lawrence River except towards the shore ends.

Q. And in those points there is considerable variation?

A. In the International Bridge Section of the Niagara River, the transverse curve is very accurately determined, on account of the bridge piers and the nature of the bottom there. It was accurately determined for as often as every twenty feet, and towards the piers more frequently, ten or five in some cases.

Q. And how accurately was it determined on the St. Clair River?

A. It is my belief it was taken every ten feet all the way across the river. I am not positive of that, but that is my belief, in the measurements made by Sabin.

Q. How many points in the cross section were actually measured in the Niagara River at the Open Section?

A. In Stations 1, 2, 3, and 17, that is about 200 feet at each end of the river, the transverse curve was measured and used in coefficient reductions. At distances of 33⅓ feet some observations were made for the transverse curve, and these were made by having a single meter at the index point and a second meter 33⅓ feet away on overhangs on a catamaran at the *sub-station point;* but in the reduction, those observations were not used. I would like to state the reason why they were not used, as set down in the report here.

Q. What page?

A. Page 5353 of the report of 1900. "In getting out coefficients, however, these substation verticals were not utilized for two reasons: first, the fixed point in the station verticals" (those are the ones marked in solid black circles on the Plate No. 7) "made their weight so great in comparison with those of the sub-stations," (the sub-stations means the 33⅓ foot points) "that it was difficult to arrive at a rational scheme of combining them. Second, the absence of current ratings as a basis for correcting the ratios made the indications of a compound instrument somewhat unreliable, so that the danger

of introducing an error seemed greater than the possibility of error from neglecting in midriver the transverse curve between stations."

In Plate No. 7, the fixed point shown by the solid black circles at the .8 depths as determined by 45 observations and at the sub-surface by 21, the bottom observations by 17,—those points were so thoroughly well established that it seemed a dilution of the accuracy of the work to attempt to introduce the transverse coefficient.

Q. Can you explain a little more fully what this difficulty seemed to be that you had in combining the observations?

A. Unless we took an equal number of observations on these intermediates, these 33⅓ foot points, the computation of the coefficient would mean the weighting of the several observations; and when I say weighting I mean, if we have a quantity measured a hundred times and we are combining that measurement with a quantity measured ten times, that former measurement having a hundred observations would have a greater weight, other things being equal, than the other.

Q. Before we get to that, is it not a fact that the reason these were discarded and not used, the first reason was that if you followed those observations you would get a different result from that which is obtained in your more reliable and greater number of observations at the index point?

A. As regards the discharge of the river, I do not know that that is the fact.

Q. Would you be able to offer any other explanation why there was difficulty in combining those observations with these non-reliable ones that you do rely on?

A. Perhaps I would better go on with the second statement, then we can talk of the whole thing together. It was found in the use of the two meters that there were slight divergences from day to day for the ratings, and the apparatus we had for observing these intermediate verticals made it difficult for us to compare one meter with another. The integrity of the two meter system depends on the fact that you combine the two meters by running them side by side in the current, and rate one with respect to the other for each day of your current work. And the apparatus for getting these 33⅓ foot points was so cumbersome that it was not easy, and was not done, as I recollect it. It was estimated that the possibility of getting an error of two per cent in these intermediate verticals was likely to give us an error

in the result greater than by not introducing the transverse curve. I have spoken of that as likely; I do not know as a matter of fact whether it would have changed the result one way or another. I was steering clear of the possibility of error and believe, now, that I chose wisely.

Q. You speak of the possibility of the meters used in these 33 foot points being likely to vary from day to day or during the same day in their rating?

A. Yes, there might be a variation the same day, possibly as much as one per cent, and from day to day there may be as much variation as two per cent.

Q. And the only reason that you have for believing that that would not be true where the observations are made at the index points is the fact that you were using two meters, one acting as a check upon the other?

A. In using two current meters in coefficient work, any slight variation as two per cent in the rating in the meter did not make any error in the percentage results because the meters were run in the current side-by-side, and the ratings were interlaced and made common in that way, so that it became a single instrument for coefficient work. When it came to discharge measurements then an error of two per cent in the absolute rating *did* make an error of two per cent in the discharge, and that was taken care of by using a number of meters, and rating them frequently; any error that might come into an individual observation being eliminated in the great multiplicity of observations.

Q. Do you remember the number of points in the cross section of Niagara, the Open Section that were actually measured in making the discharge measurements?

A. Seventeen; there were seventeen stations and a measurement at each of the seventeen stations constituting a river traverse, was a discharge measurement, taken in connection with the gauge readings.

Q. And at the International Bridge how many points were actually measured?

A. Twenty-one.

Q. Will you give us what the cross sectional area of the Niagara River at the Open Section was, also at the Bridge Section?

A. (No answer.) At 567.0 O H levels. Open 42,063 square feet. Bridge 39,335 square feet.

Q. At how many stations were observations made in the St. Lawrence, in making discharge observations?

A. At seventeen stations.

Q. Do you remember how many points in each station observed?

A. As a rule six in each discharge.

Q. And in some instances eleven?

A. At each station? No. The method there was to do the coefficient work at the same time we were making the discharge measurements; that is we had two meters and one would start (on the measurement of the discharge); it would start at the subsurface as zero and go to the 2/10, 4/10, 6/10, 8/10 depths and bottom. On the way back again, or some other discharge, measurements were observed on the odd tenths of depth, so each discharge measurement gave us a full set of vertical curves.

Q. What was the cross sectional area of the St. Lawrence River at the point where discharge measurements were taken?

A. 51,000 square feet roundly. It varied of course with the stage of the river.

Mr. Williams: I would like to have at this point Plate No. 6 marked as "Defendant's Exhibit D, June 4, 1909, Shenehon's cross-examination"; the plate following page 5360 of the Report of the Chief of Engineers for 1900.

Q. Please state the cross sectional area of the Niagara River at the International Bridge, where discharge measurements were taken?

A. At elevation 567.3, that was in levels of 1903, the cross sectional area is about 39,000 square feet.

Q. And the cross sectional area of the Open Section, what was that?

A. For the same elevation, about 42,000 square feet.

Recess to 1:45 p. m.

1:45 p. m., June 4, 1909.

The cross-examination of Mr. SHENEHON was resumed as follows:

Mr. Williams: Q. Have you now, Mr. Shenehon, the data from which you can give us the information asked for with reference to the Detroit River as it was prior to the improvements made by the United States Government?

A. Yes, I think so.

Q. What was the original depth of the Detroit River prior

to the making of improvements by the general government in the stretch from Stony Island to Fort Malden?

A. That is along the channel, along the vessel track?

Q. Yes.

A. Reading the soundings within the channel lines from abreast of Texas Dock downward, down stream for a distance of about 6,000 feet we have: 25 feet, 22 feet, 24 feet, 24 feet, 25 feet, 25 feet, 24½ feet, 22 feet, 24, 21¾, 21¾, 22¼, 22, 22¼, 23½, 22½, 22½, 23½, 24½, 19½, 18½, 18½, 18¼, 18½, 20, 18½, 17½, 18½, 14½, 16½, 15½, 15, 15½, 15½, 16½, 17, 19½, 18½, 17½, 16½, 19¼, 17¾, 17½, 18½, 19, 18¼, 17½, 16½, 19, 18½, 19¼, 19½, 20½, 20¼, 19½, 22½, 19¼, 21½, 22¼. That would be about the limit.

Q. To what does that refer?

A. That refers to elevation of Lake Erie 573.2. To compare it with the elevations on this chart, Defendant's Exhibit A, subtract from those depths 2.2 feet.

Q. Subtract from those that you have given?

A. Yes.

Q. Compute for us the discharge capacity of the Detroit River at mean stage of Lake Erie for the reach from the head of Stony Island to Fort Malden as it existed prior to the first improvements and as it will be on completion of the Livingstone channel, assuming the material from the latter work is to be distributed over the area in a reasonable manner.

Mr. Wilkerson: That question propounded to the witness is to be taken by him and answered as opportunity presents itself.

Mr. Williams: Yes, that is right.

Q. You were about to continue, giving the title of the map from which the soundings were taken?

A. The soundings read are from the Lake Survey map or Field Sheet of 1873 U. S. Lake Survey, files 1-550; and the elevation of water surface is referred to Lake Erie 573.2.

Q. Mr. Shenehon, do these tables which I now hand you, or which I have in my hand correctly show the levels of Lake Superior, Michigan, Huron, St. Clair, Erie and Ontario as indicated by the records of your office?

A. They were prepared from the records in this office and I believe correctly represent those records.

Mr. Williams: I will ask to have these papers marked "Defendant's Exhibits D, E, F, G, H, and I" cross-examination of Mr. Shenehon, June 4, 1909.

The Witness: In connection with my answer, my attention has been called to the fact that certain changes have been made on the Milwaukee record due to the settlement of the pier there; and I am not certain whether it is incorporated on this record for Milwaukee or not. It is on the *hydrograph* of one of the prior exhibits showing lake elevation.

Mr. Wilkerson: You say that change was made on the hydrograph?

A. Yes, it is correct here; I am not certain whether it was made on these tables. I believe it was though.

Mr. Williams: Q. That is on Exhibit 5, May 24, 1909, it is correctly shown?

A. That change was only a matter of a few hundredths of a foot.

Q. In the report of the Chief of Engineers for the year 1904, pages 4096 and 4097, appear tables of elevation referring to Lake St. Clair; in which tables there are elevations shown in addition to those indicated upon the sheet known as Defendant's Exhibit G. Now what would you say as to the probable reliability of those tables as showing the elevation of Lake St. Clair?

A. I don't know that these are accurate. I do not know the source of them, as a matter of fact. In the case of the Detroit River and St. Clair River, I believe Mr. Sabin gathered some data from gages outside the office; and I do not know what the reliability of the data is. I have not studied that part of the subject. Prior to, say 1870, possibly extending into the early seventies, there are in some cases doubts as to the elevations; in certain cases I believe after that time, but in the seventies was the time the Lake Survey —it was one of the periods when the Lake Survey was operating largely, and at that time things were established on a firmer basis than they ever had been before, as regards water levels. Prior to that, error may exist in some of the data.

Q. Have you any reason to believe that in these tables, which I have called your attention to, in the report of 1904, there are inaccuracies in the table of elevations for Lake St. Clair to a greater extent than, say, one-tenth of a foot?

A. I do not know. In answering that question I understand you mean the earlier observations?

Q. The earlier observations and those which are not included in this sheet after 1872?

A. In the case of Lake St. Clair, I ought to explain that some observations are interpolated from the Windmill Point

gage. Subsequent to the publication of that 1904 report, precise levels were run from Algonac to the St. Clair Flats. That was last fall and the result of those levels caused a small adjustment in the nominal elevations of Lake St. Clair. What I mean is the mean of the elevation changed by I think .06, somewhere in that neighborhood.

Q. These tables to which I have called attention were prepared in your office, were they not?

A. Yes.

Q. You considered them reliable or you would not have published them, of course?

A. Personally I had nothing to do with the publication.

Q. You made the reports, or worked on them?

A. I was not Principal Assistant Engineer at the time that report was made. I began to be Principal Assistant in 1906. I had nothing to do with the compilation or issuing of that report except my own portion of it.

Q. Will you tell us who would be the proper person to interrogate on the question of the reliability of these tables showing the elevation of Lake St. Clair?

A. Mr. E. E. Haskell, now Dean of the College of Civil Engineering at Cornell University, was the principal Civilian Engineer at that time, and the report itself was made by Assistant Engineer Thomas Russell, who is a member of the Lake Survey at the present time.

Q. Now if these tables which have been marked as Defendant's Exhibits E to I, inclusive, show that the years 1860 to 1865, inclusive, the mean difference of elevation between Lakes Huron and Erie was 8.92 feet, would that be the correct difference, as near as the same could be determined, in your opinion?

A. Is that the mean for the full year or for the open season of navigation?

Q. That is the annual mean.

A. I should say that that mean would be influenced by ice conditions and would not necessarily be the proper relation between Lakes Huron and Lake St. Clair.

Q. This is Lakes Huron and Erie I am speaking of. The question was whether or not, if these tables show that the mean difference of elevation between Lakes Huron and Erie for those five years was 8.92 feet, would that be the correct difference as near as it can be determined?

A. For that time?

Q. For that time, for that period?

A. That is between the Cleveland Gage and the Harbor Beach gage, or Milwaukee?

Q. Milwaukee gage.

A. The Milwaukee gage, for that time; I do not know of any better way of determining the difference in elevation at that time.

Q. And you would answer similarly, with respect to the period from 1866 to 1871. We are assuming that these tables show a difference of 8.68, as the mean difference between Huron and Erie?

A. That is 1866 to 1871. I do not know of any better way of determining the difference.

Q. Would your answer be the same respecting the period from 1872 to 1877 where the mean difference from these tables would appear to be 9.01, as to the correct mean?

A. I assume if the Harbor Beach gage or the gage in that vicinity were available, the results from that should be used, I think, in that determination. That was made about 1874, I think.

Q. Are the observations made at that time included in the tables?

A. For Harbor Beach, yes. Aside from any small correction from that, which would be very small, that 9.01, provided the computation is correctly made, would be the best evidence we have regarding the difference between the lakes.

Q. And for the period from 1878 to 1883, inclusive, using the mean difference of elevation of 8.8 feet?

A. The Harbor Beach gage should be used in that, in conjunction with the Milwaukee?

Q. Yes.

A. Or independent of it?

Q. Which did you mean, in connection with it or independent of it or both?

A. They give practically the same result, so it is rather immaterial, it will not make much difference.

Q. Then that would be the correct difference as near as you can arrive at it?

A. It appears to be, yes.

Q. And for the period from 1884 to 1889, if the mean difference of elevation between these lakes appeared from these tables to be 9.18, would that be correct as near as it can be determined?

A. Yes, I think that is the proper—

Q. For the whole period covered from 1860 to 1889, in-

clusive, the average difference appears to be, from these tables, 8.91 feet. Is that correct?

A. I am assuming the correctness of your computations in this.

Q. Assuming that that computation is correct, and that the computation is based upon these tables, would you say that that was a correct average for those years, or would you say that there was any method of determining that mean difference any more accurately than that?

A. The mathematical process used insured the fact that it is the average, by the definition of average.

Q. Can you give any explanation of the fact that Mr. Wheeler in his testimony gave the average for the period from 1860 to 1880 as 8.52; assuming that our computation is correct? Have you any information as to how he arrived at that conclusion?

A. What do your computations make it for the same period; that is from 1860 to 1880?

Q. The ten-year periods do not end with 1880. Taking it clear to 1889, and the period from 1884 to 1889, which is the highest of any of them, gives it 8.91; taking it up to 1883, it gives 8.8?

A. Well, I do not think the process that you are using is a valid one, of comparing periods other than the same periods Mr. Wheeler used.

Q. Do you know what periods he used?

A. You have just said he used the period from 1860 to 1880. You cannot compare different periods and get the same result, unless the mean elevation of one of the lakes, at least, is the same for the two periods.

Q. These ten-year periods, all of them, show a higher average than the value which Mr. Wheeler got, this group, and it does not seem as though it would be proper to drop in there with something that would give a greater average for those twenty years than that made up of the ten-year period running on through?

A. My own computation for the years 1860 to 1879, both inclusive, gives 8.85. I do not know how Mr. Wheeler got his result; and it is possible that it comes in the old levels, the adjustment. He might have used his own tables in the 1903 report.

Mr. Wilkerson: By that you mean there has been an adjustment in these tables from time to time?

A. Yes, in the adjustment of the levels a certain correc-

tion was applied at Cleveland to bring them up to what we call the levels of 1903, and there was a difference also at Harbor Beach and Milwaukee.

Mr. Williams: Q. Those were taken into consideration in these tables, were they?

A. Yes, those tables are on 1903 levels.

Q. And if these tables show a mean difference from 1890 to 1908 of 8.4 feet, that would be as nearly correct as you can determine it?

A. That is the last period from 1890 on?

Q. 1890 to 1908?

A. Well, I would like to point out that your method of extending your period beyond 1880 to include the high water of 1886, and then in your second period including the low water of 1895, is hardly a fair one.

Mr. Wilkerson: Q. That would explain that difference to a very large extent?

A. Yes.

Mr. Williams: What difference?

Mr. Wilkerson: The 8.8—

Mr. Williams: That was prior to 1880.

The Witness: In high water Lake Huron will go up higher than Lake Erie, so the difference becomes greater as the stage increases. Including that high water of 1886 in your earlier average and including in your later average the low water of 1895, you get the lights and shades contrasted in a way that is not fair. For the 10 years between 1860 and 1879, I get a difference of 8.85; and for the years from 1880, including the year 1908, I get 8.62 as the difference. For the two periods considered, the fall between the lakes is .23 less in the latter period than the earlier one; and just what the stage of Lakes Michigan and Huron was at that time I have not computed. That would have some small bearing on that.

Q. Can you very quickly compute and give us the result of the computation, showing the difference for the period from 1890 to the present time?

A. Yes. 8.41.

Q. Now taking it on this assumption that for thirty years from 1860 to 1889, inclusive, the average fall between Lake Huron and Lake Erie was 8.91; and that for the nineteen years from 1890 to 1908 it was 8.41, to what would you ascribe the change of .51 feet, .5 of a foot, practically six inches?

A. In the earlier of the two periods mentioned, Lakes Michigan and Huron had an elevation of 581.71, and in the

latter period 581.05, as I compute it, making a difference in the stage of Michigan and Huron of .66 of a foot. Now on account of the higher stage of Lakes Michigan and Huron, you would expect the difference on Erie to be 70 per cent of 66, that is the ratio of the movements of the two lakes. You would expect the difference in level between the lakes for those two periods to be 0.46 foot apart, and I think you made it out .50; it checks within half an inch.

Q. Do you mean that if Lakes Huron and Michigan were six inches higher at a certain period than at another period that two-thirds of that excess in elevation would remain as a difference of elevation between the two lakes?

A. I mean to say that if you will plat Lake Erie with respect to Lake Huron you will find out that their elevations vary somewhat in the ratio of 100 to 70 or 100 to 70 per cent. By that I mean if Lake Huron goes up a foot or is a foot higher in any particular period, Lake Erie is .7 of a foot higher at the same time. That is an approximation you understand.

Q. If Lake Huron goes down a foot, what is the effect on Lake Erie?

A. As shown by the gage readings, that relation holds, lake goes down 0.7 foot.

Q. About .7?

A. About .7; or if Lake Erie goes down a certain amount, Lakes Michigan and Huron will go down the reciprocal of 7, which is somewhere in the neighborhood of 40 per cent greater. That is about 43 per cent in excess; and that is one of the reasons that I gave why I considered that the lowering, in the case of Lakes Michigan and Huron by the diversion at Chicago was likely to be in excess of the lowering caused on Erie. I took the case where the increment is most accurate, in the Niagara River, where we have a range of four feet. We find that the lowering is 2¼ inches. And if the lowering of Michigan and Huron is derived by means of that relation, it will be 40 per cent greater on Lakes Michigan and Huron, but that process is rather involved, and hardly defensible, in getting at it in that way.

Q. Mr. Shenehon, diverting from the regular course of procedure outlined, will the effect upon the elevation of Lake Erie be greater or less than that upon the elevation of Lakes Michigan and Huron, assuming that the elevation is changed by reason of the diversion at Chicago?

A. In my evidence on that point I showed the increment

of the Niagara River to be 22,000; and I stated the increment of the St. Clair River was 24,000 with a possible error of 25 per cent, which would reduce it to 19,000 if the full percentage was applied; and that indicates that I consider that the lowering on Lakes Michigan and Huron will be greater than on Lake Erie; I stated between 2 and 2½ inches, and I did not give much weight to that consideration of the relative movement of the two lakes, and yet if you will plat them it is astonishing with what precision in five-year periods the lakes will follow this line.

Q. Assuming that is true, have you any explanation to offer as to why this difference in mean elevations actually occurs?

A. For one period there is a certain mean elevation that is higher than for another period?

Q. Why there is a greater difference in one case than in another. You testify you think it is true?

A. If the increment of the St. Clair River were greater than that of the Niagara River, we would expect the fluctuations in stage at different periods to be greater. In a small pool that is a very clear relation. In the big lakes, the reservoir effect masks it to some considerable extent.

Q. In 1889 it appears that the difference in elevation between Lake Erie and Lake Huron, assuming this (indicating chart) to be correct now, is practically 8.9 feet?

A. Yes.

Q. The next year the difference in elevation is 8.1, or less. Now what I would like to have you do, if you can, is to explain why those variations in difference exist. We can understand the reason why the lake is higher at one time than another and why one lake is lower sometimes than at other times, but why is there the variation in difference of elevation of the two lakes, in so short a period?

A. That is about 0.8 of a foot, is it, the difference?

Q. Yes.

A. The curve of the water level of Lake Erie, as shown on Exhibit 5, shows steadily rising water for Lake Erie, beginning with November, 1889, continuing through the winter and up to June of 1890. The curve of Lake Huron beginning with December, 1889, shows lowering levels, up to March, 1890. The indications are that ice in the St. Clair River did not interfere with the flow of the St. Clair River, but during the winter season it continued to send good volumes of water to Lake Erie. It is possible that ice conditions in the Niagara

River had something to do also with allowing Lake Erie to climb up. Local climatic conditions, as large rainfall on the Lake Erie basin might have entered, while the precipitation on Michigan and Huron basins might have been small. The year selected is, so far as I can see, the most abnormal year since 1875, and the discrepancy of 0.8 between those years is not one that need give us any serious concern. The ice conditions and local rainfall effects may accumulate in one year out of twenty-five or thirty, so that we will get a condition that is as extraordinary as the one you speak of.

Q. Look at the year 1903, would you consider that same explanation as applicable to that year?

A. You mean the year 1901?

Q. 1903?

A. That is 0.4 of a foot difference for that year.

Q. Yes.

A. That is between the year 1903 and 1904 on one side and 1902 on the other.

Q. I understood you to state you considered this an abnormal year. I was only calling attention to the fact—

A. I mean as regards the difference between the two years; this is 0.4. I said it was the most abnormal year—

Q. Take 1901-2?

A. 1901, I have already called attention to in this case as a year of extraordinary ice conditions; and I think perhaps the ice condition will explain most of these differences; that is this large difference. In 1901, my evidence earlier in the case, shows the conditions were very abnormal. Did you want an answer to 1903?

Q. Yes, if you can give it?

A. That 0.4 is probably due to absence of ice effects in 1903, and difference in local precipitation, evaporation, and those elements in the case.

Q. To what would you ascribe the general tendency of a decrease in the difference of elevation between the two lakes, indicated by the fact that the average difference during the past twenty years is approximately 6 inches less than it was during the twenty years preceding?

A. I have already testified along that line.

Q. I did not get the explanation in my mind. I do not know whether it is in the record as to why the general tendency decreased. You gave an explanation of the specific years where there were abnormal years. Now the general

average for the past ten years appears to show a difference of elevation of 6 inches less than the preceding twenty years?

A. In the early period from 1860 to 1889, inclusive, the elevation of Lakes Michigan and Huron was 581.84. In the latter period from 1890 to 1908, inclusive, the elevation was 580.53, a difference of 1.31. Now Lake Erie, we expect to go down 70 per cent of Huron's lowering, which is .92, and the difference between 1.31 and .92 is the increased difference in level you would expect, which is practically 0.39; and I think you stated it to be .5 of a foot.

Mr. Wilkerson: You substitute the figures you give now for the ones you gave a few moments ago, is that right?

A. Yes, if the period is the same.

Mr. Williams: Yes.

Mr. Wilkerson: Assuming the period is the same, this amended computation that has been made here gives the figures more correctly than the other ones?

A. Yes.

Mr. Williams: Q. I understand that when there is a variation in the elevation of Lakes Huron and Michigan of 1.31 feet, or a lowering to that extent, that there is a lowering in Lake Erie of 70 per cent of that amount; and the 70 per cent of that amount deducted from the lowering in Lakes Huron and Michigan accounts for .4 of a foot difference. But what I am trying to get at is, have you an explanation to give why there is 70 per cent of that difference noticeable in Lake Erie, instead of 100 per cent or 120, or any other per cent?

A. That 70 per cent is a very approximate figure.

Q. Why isn't there just as much of an effect in Lake Erie as there is in Lakes Huron and Michigan? Why is it 70 per cent, or any other per cent?

A. It is 70 per cent because the observations show that the thing is running that way.

Q. But do you have any reason for it except that you have noticed that it was a fact?

A. I have stated that the reason I think, the controlling reason, is the fact that the increment in the St. Clair River is really smaller than the increment in the Niagara River. Let me make that clear: in the case of small pools where the reservoir effect does not enter so largely, and we can see the thing very much more clearly, if we know the increments of two pools as for instance the Whirlpool and the pool in the Niagara River above the Rapids, above the cataract; if we

know that the increments are in the ratio of 2.50 to 0.56, we know very well that the fluctuations would bear the inverse ratio. It is not entirely certain that when you take larger reservoirs like Lakes Michigan, Huron and Erie that you can —rather it is very certain that you cannot—argue with the same certainty that you would in the case of these smaller pools. The local supply, local runoff, local evaporation, those elements are likely to enter in, and I do not want to state, on the face of that, clearly that I know the increment in the St. Clair River is smaller than it is in the Niagara River; but I think it is a clear proposition.

Q. Will you state it as your belief that the increment in the St. Clair River is smaller than that of the Niagara River?

A. I have already done that in my evidence, yes. I gave that as one of my reasons why I thought 25 per cent was not an improbable error in the increment as it was set down on the chart, which shows 23,820.

Q. Suppose, Mr. Shenehon, that when an examination of the discharges were made with reference to the lake elevations it were found that for a known elevation of the lake there were two different discharges. Would you account for this as being probably the result of erroneous gage readings, within the limits that you have previously stated for the several gages?

A. No.

Q. How would you account for that?

A. I would account for it, if it might be in the Niagara River, for instance, that with a rapidly rising Lake Erie level at Buffalo, the river might not be in stable equilibrium as regards the flow.

Q. Suppose it were in the St. Clair River?

A. In the St. Clair River, that comes with stronger force even than the Niagara River, on account of greater length and the more complex condition entering, from Lake St. Clair's backwater effect.

Q. Taking into consideration the methods employed by the government in making these discharge measurements, what in your opinion is the probability of the gaging showing too high a discharge?

A. In which particular river?

Q. Take the St. Clair River?

A. For the mean condition as regards Lake Huron elevation and Lake St. Clair elevation, I believe the volume of discharge is accurate within one to two per cent.

Q. And if there be any error, do you think it would be more likely to show too high a discharge or too low?

A. Just as likely one side as the other. I see no reason for either having a preference.

Q. What situation might conduce to an observation showing a discharge actually in excess of that which was in the stream?

A. If when the meters were being rated, additional friction on the wheel, due to some causes that might enter, possibly a little silt on the disc or the shaft, possibly a weed caught on the wheel,—and then the instrument were taken to the river and the discharge made in which there was no silt on the meter wheel, no silt on the shaft, no weeds caught on the wheel, you might have a very small percentage greater discharge indicated, under those conditions. The probability, however, of these frictions on the disc, or on the shaft of the meter coming in, or anything in the form of weeds coming across the meter wheel, are very remote.

Q. Assuming that the meter has been correctly rated, then what situation could arise that would cause the meter to show too high a discharge?

A. A possibility enters of a little oil getting on the disc of the wheel, so that in the revolution of the wheel, instead of getting a single movement of the register, it doubles up, that is what we call skipping; that is a thing that is constantly listened for while the meters are in operation, and if that escaped the attention of the observer, your register might show a few more revolutions than were made by the meter wheel. That condition, however, is constantly watched for, and is very apparent when it does occur. It breaks the rhythm of the register sound.

Q. What would be the effect on the meter of currents in the river running obliquely to the section?

A. That is taken into account in the reduction of coefficients. We make a reduction for the direction of the current. Observations are made as to whether or not the current is cutting the section at right angles; if it is not, we introduce that into our velocity coefficients. No error will enter from that cause.

Q. What will be the effect on the meter of having the current strike it obliquely as compared with having it strike at right angles to the section?

A. The tail which controls the direction of the meter holds it nose on to the current.

Q. So that the meter always is absolutely parallel with the direction of the current?

A. Absolutely is too strong a word. I should say that the meter bears the same relation in its truthfulness with the thread of the current as it does in its truth to the direction of the rating base. If this occurs at all, it is eliminated between the rating base and the river; so that no error enters of that kind.

Q. Is a meter likely to increase the number of revolutions for a given velocity during a gaging?

A. It might, yes.

Q. To what extent?

A. One to two per cent.

Q. Can you account for that?

A. The meter might show cause by this skipping I have mentioned, this oil on the disc, why it should be cleaned, and upon taking it out and cleaning it and putting a little more oil on the pivot, you might better the lubrication. The lubrication, however, has very small effect on the spinning of the wheel.

Q. If floating material such as grass or weeds were to catch on the meter, would that effect be to increase or decrease the amount of discharge shown?

A. The lodgement of weeds or grass on the meter wheels, in my experience, has been practically zero.

Q. Assuming that there was such a thing?

A. The claim made in the patent for the Haskell meter is that it will throw off weeds; that the wheel is pointed at the nose, and it is rounded for the purpose of throwing off weeds if they should come along. If a weed did lodge square across the nose, it would slow up the wheel,—give fewer revolutions.

Q. Indicate a smaller velocity of the stream?

A. Yes.

Q. Until the weed was thrown off?

A. Yes. I know of only one case where weeds have entered into consideration, and that was in the observations in the power canal at Niagara Falls, in the fall of the year. Weeds in the lower Niagara River grow to very large extent, and towards fall they are loosened up, come down the river, and for a few days in 1907, the fall of 1907, the weeds gave some considerable trouble, mainly in accumulating across the vertical standard which carries the lead weight, and across the cable. That was a transient condition and due to the fact that the power canal is below a great mass of weeds,

the mass of weeds is so great there that it is difficult to get a small boat through. It must be understood that in the Niagara River, and I presume it is true also in the St. Clair, that the rivers themselves are not silt bearing, and there are few weeds. That is equally true of the St. Lawrence; the water is running clear, and as to the coming down of weeds there, I recollect none in my experience on the St. Lawrence River.

Q. What is the effect on the discharge of the St. Clair River of a rise in Lake St. Clair, will it increase it or decrease it?

A. A rise on Lake St. Clair decreases the discharge of the St. Clair River.

Q. A fall in Lake St. Clair would increase the flow in the St. Clair River?

A. Yes.

Q. Taking the plate, Government Exhibit 1, is the effect of the elevation of Lake St. Clair, taken into effect in determining the increment of the St. Clair River?

A. The observations are platted as indicated by the Huron gauge without change, except in the case of 1901 which is explained in this note. That was adjusted.

Q. The observations as to the elevation of Lake St. Clair?

A. The 1901 observations are adjusted for the abnormal stage of Lake St. Clair. That was the ice year, in which Lake St. Clair was low.

Q. Those observations that are platted on that plate indicate the level of Lake Huron and Michigan and the discharge through the St. Clair River, and the relation that one bears to the other?

A. Yes; and when I say the elevation of Lakes Michigan and Huron, it is the elevation of Lake Huron at Harbor Beach, which is set down here.

Q. The question is are the elevations of Lake St. Clair platted on that plate in any way?

A. No.

Q. Are they taken into account in any way in determining the increment according to the formula that appears on that plate?

A. Aside from the observations of 1901, no attention is paid to Lake St. Clair. Lake St. Clair is eliminated by the relation between Huron and Lake St. Clair. I do not mean by that that any manipulation of the figures was made. I simply say the period between 1899 and 1900, excluding 1901, 1902

and 1908, Lake St. Clair is taken for that period as being at a stage that is normal.

Q. That is you assume Lake St. Clair to have a certain elevation, which you arrive at from the elevation shown in Lake Huron and not by actual gage readings in Lake St. Clair itself?

A. Derived from the gage readings, yes.

Q. Gage readings of Lake Huron?

A. Lake Huron and Lake St. Clair both; that is platting one with respect to the other, just as they are on here (indicating plate).

Q. Please explain how you took into account in determining the increment of the St. Clair River the elevation of Lake St. Clair, at the time that observations were made as to the elevation of Lake Huron, and the discharge measurements were taken?

A. The discharge observations extending through four years, 1899, 1900, 1902 and 1908, are taken as extended enough to warrant a normal relation existing between Lake St. Clair and Lake Huron.

Q. What is that normal relation?

A. It is somewhere in the vicinity of a change of one foot on Lake Huron showing a change of 0.66 of a foot on Lake St. Clair. That 0.66 enters in no wise into the making of this plate (indicating Exhibit) except as the observations of 1901, which are not used in the computation here, have been adjusted to bring them up to a normal relation of Lake St. Clair.

Q. What do you consider the normal difference between the two lakes?

A. The plat as made here is made just as if we had no gage relations on Lake St. Clair; it is ignored.

Q. That is what I was trying to get at.

A. The discharge is taken as depending on Lake Huron stage, with the understanding—

Q. And on the assumption that Lake St. Clair is in a normal relation to Lake Huron all the time, or is stationary.

A. (No answer.)

Mr. Wilkerson: Q. You ignored that because at the time of the observations the gage readings showed the relation to be normal, is that right?

A. The fact of the normal relation of Lake St. Clair with respect to Lake Huron depends entirely on the length of

time over which the observations existed, and nothing further.

Mr. Williams: Suppose that in the group of observations Lake Huron rose, and Lake St. Clair rose at the same time; would the effect of the rise in Lake St. Clair increase or decrease the apparent increment due to the change in Lake Huron?

A. If Lake St. Clair rose at such a relation or made such a proper percentage rise of Lake Huron, the increment would not be affected.

Q. Would the rise of Lake St. Clair in itself increase or decrease the apparent increment?

A. If Lake Huron remained stationary and Lake St. Clair should go up say a tenth of a foot, the discharge would be lessened about 1,600 cubic feet per second; that is at the time when the discharge was about 200,000 cubic feet per second.

Q. When the discharge was decreased to that extent, the increment would be larger?

A. The increment is the difference of the discharges per foot change in Lake Huron stage; and we have got to take into account two of them, instead of a single one, to get at the rate of change, or the increment.

Q. Assuming that the raising of Lake St. Clair would cause a decrease of flow, if Lake Huron rose a foot, that rise of Lake St. Clair would cause a decrease of the apparent increment, would it not?

A. Now, let me see: you want Lake Huron to go up a foot. What is Lake St. Clair to do meanwhile?

Q. Suppose it goes up a tenth of a foot. Suppose Lake St. Clair is stationary to start with, does not go up at all?

A. And Lake Huron goes up a foot?

Q. Yes, and the level of Lake St. Clair is not changed?

A. I do not think that our formula would give accurate results with so large a difference in Lake St. Clair and Lake Huron.

Q. Suppose that there was a rise of .2 of a foot on Lake Huron, and Lake St. Clair remained stationary?

A. That would show an increased outflow, say with an increment of 24,000 of plus about 88/100 of one per cent of the volume of flow for lessened backwater. We take the backwater effect, that is the retardation of the outflow due to Lake St. Clair as about two-thirds of one per cent for each tenth of rise in Lake St. Clair; two-thirds of one per cent

of the volume of flow. That is an approximation, and I do not know—

Q. Are you assuming Lake St. Clair has remained stationary and a rise of .2 of a foot in Lake Huron?

A. Yes.

Q. The increased flow in such an event would be how much?

A. If your base flow was 200,000, it would be about 6,570 cubic feet per second.

Q. And suppose there was a rise of .2 of a foot in Lake Huron and a rise of one-tenth of a foot in Lake St. Clair, what would be the increase of discharge in St. Clair River?

A. That would be 5,240 cubic feet per second increase.

Q. Assume both lakes rise simultaneously .2 of a foot, what would be the additional discharge of the St. Clair River?

A. That would be about 3,900 cubic feet.

Recess to June 5th, 1909, 9:30 a. m.

June 5th, 1909, 9:30 o'clock a. m.

Cross-Examination of F. C. Shenehon resumed.

Mr. Williams: Q. In dealing with the Niagara River, is it necessary to consider the changes of elevation anywhere except in Lake Erie, in determining the increment in the Niagara River?

A. As a mean of the open season flow, no.

Q. And in dealing with the St. Lawrence River, would it be necessary to consider changes of elevation anywhere other than in Lake Ontario?

A. The St. Lawrence River, at the head of the Galops Rapids is the place in the river where the elevation of the water determines the outflow; in the vicinity of the Galops Rapids.

Q. In determining the increment of the St. Lawrence River, did you observe the observations of elevation in Lake Ontario?

A. The observations of Lake Ontario are made simultaneously, that is the water surface observation, tri-daily observations at Oswego, and the self-registering gage at Tibbitts Point, which is at the head of the river; also self-registering gage at Ogdensburg. Aside from the time when ice condi-

tions enter, the elevation at any one point permits us to derive the elevations for the other three points mentioned. That is the slope in the river above Ogdensburg is something less than a foot, normally about 0.85 foot, as I recall it, and from Ogdensburg to the Galops in the neighborhood of two feet. And when the water goes down a foot at the head of the Galops Rapids, it goes down a foot and two hundredths at Ogdensburg and a foot and four hundredths in Lake Ontario. The movement is almost identical, a little bit larger on Lake Ontario.

Q. Did you take into consideration in arriving at your increment, anything other than the elevations of Lake Ontario, and your discharge measurements in the St. Lawrence River?

A. The increment as derived is with respect to the water surface at Ogdensburg.

Q. Is it necessary to take any elevations anywhere else other than Ogdensburg in arriving at the increment?

A. To arrive at the increment? None other aside from those incident to the discharge measurements on the section.

Q. Is it your opinion, Mr. Shenehon, that the average difference of elevation, or fall from Lake Huron to Lake Erie, as indicated by the observations from 1890 to 1908, will be substantially permanent?

A. The elevation for Lake Erie for that period appears to be nearly half a foot below the mean stage of Lake Erie, since 1860. The permanence of that level, and by that I presume you mean over long periods of years, as ten or twenty years, is likely to be interferred with by artificial changes. Increasing diversion at Niagara Falls may have some small influence in lowering Lake Erie; possible larger diversions in the Welland Canal; possible larger diversions in the Erie Canal.

Q. Eliminating the artificial changes, such as you have indicated, what would you say as to the probable substantial permanence of the average fall, as indicated by the observations from 1890 to date?

A. I know no reason why the difference in elevation between Lakes Huron and Erie should be largely different from the difference 8.4, for that period. And when I say that, it might vary a tenth or two either way. And in this statement I am assuming periods long enough to eliminate eccentric variation such as you pointed out in the year 1890, I believe it was.

Q. Now, going back perhaps a little: if the conditions existing today are substantially permanent conditions, and the present difference in elevation of these two lakes is not due to temporary local conditions, can you state why the difference in elevation between these two lakes for this period from 1890 to 1908 is less than it was for the period of thirty years preceding 1890?

A. In the thirty years, the earlier period to which you refer, the elevation of Lakes Michigan and Huron was 581.84, and the fall between Michigan and Huron and Erie is 8.92, as I have just computed it. In the latter period, beginning with 1890, the elevation of Lakes Michigan and Huron is 580.53, and the fall is 8.41. This shows that Lakes Michigan and Huron are 1.31 feet lower for the latter period than for the former, and that the fall between them is 0.51 feet less for the latter period, when the lakes were low, than for the earlier period when they were high. I explained yesterday that in a general way, when Lakes Michigan and Huron go down one foot, Lake Erie goes down about 70 per cent of that, .7 of one foot. In these two periods, Lakes Michigan and Huron went down 1.31, and 70 per cent of that would be .92, and the difference between these is 0.39. That checks within .12 of a foot or an inch and a half of where we would expect Lake Erie would be, knowing where Lakes Michigan and Huron were, which is a very close check.

Q. What was the average elevation of Lake Erie for the latter period as compared with the former?

A. For the earlier period, 572.92, and for the latter period 572.12; that is Erie is .8 of a foot lower, where the computation I have made would expect it to be .92 of a foot, which is within an inch and a half of—

Q. Do you ascribe the lowering of the elevation of Lake Erie entirely to the fact that the elevation of Lakes Michigan and Huron has been lowered?

A. I should say that while Lake Erie's stage depends upon the supply that it gets from the St. Clair River and Detroit River to a large extent, that its own particular elevation involves local conditions as well; and by that I mean local rainfall, runoff and evaporation and elements of that kind, that enter into the problem.

Q. Is there any other reason in your mind why Lake Erie has been, as an average elevation, .8 of a foot lower than it formerly was, except the change in elevation in Lakes Huron and Michigan?

A. I have made no analysis of the rainfall and evaporation and runoff data.

Q. Do you consider that the fall in the elevation of Lakes Huron and Michigan would be sufficient cause for the lowering of the elevation of Lake Erie?

A. I do not attempt to explain the elevations of the lakes, at any time; to say why this lake is there, or why the other lake is at that particular point. For the period mentioned, as indicated by the computation I made, the lakes seemed to bear the proper relation to each other, and that is simply a matter of history. If you plat the records of one lake with respect to the other, in a general way they line up so as to indicate a movement of 70 per cent on Erie for one foot on Lake Huron, and for the particular period that relation seems to be borne out by the computation I made very closely. If you mean local diversions, Mr. Williams, in your question, as to whether more water has been used in the Welland Canal in recent years—

Q. No. What I was trying to get at is why the level of Lakes Huron and Michigan has been lowered by 1.31 feet and the level of Lake Erie has been lowered .8 of a foot in a period from 1890 to the present time, what caused the lowering of those lakes, that is what I am trying to get at.

A. I think the inclusion in that period of the extreme low water of 1895 explains why the mean is lower than the earlier period. That as I understand was a period in which we had record low water all over the country; not only in the great lakes, but in other rivers as well. The former period includes the period of 1886, which was the record high water. Since 1860.

Q. Suppose we eliminated both of those years, you would still find, would you not—

Q. Suppose we eliminate the low water of 1895, eliminate it entirely?

Mr. Wilkerson: I understand the periods we are talking about are the periods ending in 1889 inclusive, and then commencing with 1890 and running down to 1908?

Mr. Williams: Yes.

Mr. Wilkerson: So that the high water period, high water year as they call it, is in the first period, and the low water is in the second period. That is correct isn't it?

Mr. Williams: That is correct.

Mr. Wilkerson: So there will be no compensation, if the

one would balance the other, because they are in different periods.

Mr. Williams: Eliminate them both.

The Witness: I think it should be written into the records that this latter period does contain the artificial diversions of which I have spoken, while the earlier period does not.

Q. Do you want to be understood as saying that in your opinion those artificial diversions are accountable for the lowering of the elevation?

A. I want to be very clearly understood as saying that whatever diversion has taken place at Chicago has had its effect upon the lakes, and increased diversions in the Welland Canal have doubtless had an effect on Lake Erie.

Q. The diversion through the Welland Canal amounts to how much?

A. 1800 cubic feet per second, as I understand it.

Q. And formerly it was how much?

A. When I state that, I take it from the statement of the superintendent of the Welland Canal. I have made no measurements there; the Lake Survey has made none. As to what they were the prior period, I do not know, but I assume that they have been increased somewhat.

Q. Assume that all the diversion through the Welland Canal has taken place during the second period, what would be the effect of that diversion on the level of Lakes Erie, Huron and Michigan?

A. It would be somewhat in the neighborhood of an inch on Lake Erie.

Q. Is there any other reason that you can give for the lower elevation of these lakes?

A. Other than artificial, or other artificial reasons?

Q. Any reason that appeals to your mind as a good reason why the level of the lakes is lower in the second period?

A. I think there is a fair presumption that improvements for channelways, if I am getting at what you desire, may have had some small influence in lowering the lakes.

Q. How small in your opinion?

A. And when I state that I wish to state at the same time that other changes entering into the rivers, as the building out of docks, the deposition of dredged material, the encroachments opposite cities, and so on, have tended to compensate any lowering that might come from improved channels. I do not see any evidence between these two periods, between the period of the earlier thirty years and the latter

period after 1890, in the relative elevations of Lakes Michigan and Huron, and Erie to indicate that any large change has taken place in the regimen of the St. Clair River or of the Detroit River. So far as that evidence goes, it would indicate that the compensation is very close to complete.

Q. Well, then, in your opinion, the improvements in the channels have not contributed to this lowering?

A. Have not largely lowered the levels.

Q. What we are trying to get at is, what are the elements that in your opinion have contributed to the lowering, not those which you have not found?

A. I assume that the latter period has an entire permanence, and as I stated earlier, that the lakes were during that period somewhat below the mean lake level; and I perhaps might read into the evidence here the elevation of Lakes Michigan and Huron: for the period 1865 to 1869 it is 581.12; and for the period 1870 to 1874 (these are five-year periods), 581.47; while for the period 1905 to 1908 the elevation is 581.02. The last is a period of four years, and the last four years we have compared with the period beginning at the Civil War, and for the ten years, 1865 to 1874, the mean elevation is 581.30, which is about 3½ inches higher than the water has been during the last four years. That is, a period of ten years beginning about the Civil War in which the elevation of the water surface is only 3½ inches higher than the period for the last few years. The comparison of the two periods, as the thirty year period of your former statement and the twenty year period of the latter, is not entirely conclusive as to the fact that the lakes are permanently lowering. Yet to a certain extent it is presumable that they are, by reason of the diversions to which I have already referred, by channel improvements and of possibly very small influence coming from the power development at Niagara Falls. That last I do not think would exceed over half an inch on Lake Erie.

Q. You spoke of the diversion of water through the Welland Canal lowering the level of Lake Erie. Does that affect the level of Lakes Huron and Michigan in any way?

A. On the assumption that the lowering of a foot on Lake Erie would have the backwater effect of one-third that amount on Lakes Michigan and Huron, it would, yes.

Q. The diversion through the Welland Canal is one influence which you have mentioned. The effect of that would be one inch on Lake Erie, and one-third of an inch approxi-

mately on Huron and Michigan. Now what other diversions do you have in mind when you speak of diversions—

A. There is about seven or eight hundred cubic feet in the Erie Canal. I do not think that has increased largely between the two periods.

Q. Assuming that it was all taken out during the latter period and that there was none diverted in the preceding period, how much of an effect would that have on the level of Lake Erie?

A. That is the sum of the effects of the Welland and the Erie, is that what you mean?

Q. Just the Erie. You have given us the Welland, give us the Erie alone?

A. For 800 cubic feet would be less than half an inch.

Q. In Lake Erie?

A. Yes, it would be just about a half an inch. Welland Canal I think is about an inch and the Erie Canal is less than a half an inch.

Q. And the diversion through the Welland would be 1800 cubic feet?

A. Yes.

Q. The effect on Lakes Huron and Michigan of that diversion through the Welland Canal would be about one-third of the half inch?

A. Yes, a little less than that.

Q. What other diversions are there?

A. There is a possible lowering of a half an inch due to the power companies at Niagara Falls.

Q. About 1/6 inch of a fall on Lakes Michigan and Huron from the same cause, then? Are there any other diversions?

A. I wanted to find in my report on the preservation of Niagara Falls a statement concerning the changes in Niagara River; I do not find that reference. The purport of it was to show that for any dredging of the river, creation of artificial channels for navigation, that compensating effects have been introduced by the depositing of material and by the encroachment of docks on the shore line.

Q. We are still on the question now of the diversions that you have in mind as having been responsible for the lowering of these lake levels; and in addition to diversions, any other evidence, which in your opinion contributed to that lowering.

A. I think I have stated them all; the Chicago Drainage Canal; the difference in flow in the Welland Canal (an un-

known quantity to me); possibly small effect due to the power diversions at Niagara Falls, and channel improvements.

Q. How much effect do you attribute to the diversion through the Drainage Canal?

A. In the ratio of 4,000 cubic feet to two inches and a quarter.

Q. What do you understand the diversion has been in the past nine years?

A. I do not have the total. I believe the license is to divert 4,167 cubic feet per second.

Q. You would attribute 2½ inches then about, or 2¼ inches of this lowering to the diversion at Chicago, that is in Lakes Michigan and Huron?

A. Yes.

Q. Assume that the maximum diversion through the Sanitary District Canal at Chicago has been 5,630 cubic feet per second, and figuring upon that basis, what has been the effect on the levels of Lakes Huron, Michigan and Erie?

A. That is figuring on a continuous flow of that amount since 1900?

Q. Assume that. It is more than the actual flow has been, but taking that as a maximum flow during any period, and assume that as a constant flow?

A. That is 56 hundred, roundly.

Q. Yes.

Q. Yes.

A. It, however, is not a fact that 56 hundred has been diverted continuously since 1906, so the answer is an assumption.

Q. Yes.

A. About three inches.

Q. That is for Lakes Huron—

A. That is Lake Erie.

Q. That is for Lake Erie?

A. Yes.

Q. What is the effect on Lakes Michigan and Huron?

A. Between 2¾ and 3½, speaking roundly, on Michigan and Huron.

Q. Now then, have you mentioned all the causes which occur to you as having—

A. I imagine variations in rainfall, evaporation and so on, enter in.

Q. Have you made any examination of the rainfall data for those periods?

A. No, I haven't.

Q. And if the data indicated that the rainfall had been greater during the latter period than the former, what would you say then as to that having contributed to the lowering of the lake level?

A. I should want the evaporation data and know that it was sound, taking it into account also with the rainfall data. I should want also to know the ice condition existing in the St. Clair River and the Niagara River. I should not want to make a judgment by leaving out much of the important data on which a judgment could be based.

Q. At present then, without further investigation, you know of no causes other than those which you have enumerated which in your opinion would contribute to the lowering effect which has been observed on these lakes?

A. No.

Q. We have accounted for 5 inches of the fall in Lake Erie, and 4.17 inches fall in Lakes Huron and Michigan, by assuming that the entire diversion through the Welland Canal has been, during the latter period—

A. Which I believe is not true.

Q. Which is not true?

A. I should say it is not true; I think there is no large increment through the Erie Canal.

Q. And allowing that the Erie Canal has been a source of or a means of diversion in the latter period, which had not been previously, which is not true; and assuming the maximum flow through the Sanitary District Canal, which is not true, and in spite of all those the results account for only 4.17 fall in Lakes Huron and Michigan, and a fall of 5 inches in Lake Erie. Do the fluctuations on Lake Erie depend entirely on those of Lakes Huron and Michigan?

A. Before answering that question, I would like to put in one other element that has entered into this case, I think.

Q. That is has contributed to the lowering effect?

A. Yes.

Q. All right.

A. That is the impounding of water in Lake Superior that came with the building of the International Bridge and the Chandler-Dunbar wing dam. Lake Superior was raised during this latter period by both of those effects; by the International Bridge in part, and by the Chandler-Dunbar wing dam cutting off the flow in spans one and two of the International Bridge; and whatever water was impounded in Lake

Superior at that time was held up from the lower lakes. Lake Superior made a rise of somewhere between 4 and 6 inches, as I remember it.

Q. In your opinion what would be the extent of the effect on the elevation of Lakes Michigan, Huron and Erie of the works that you have just mentioned?

A. I could not state that, without a rather long computation.

Q. Would it be greater or less than the effect on Lake Superior itself; that is the corresponding effect? You say that Lake Superior had a higher elevation of from 4 to 6 inches. Would it make more or less than 4 to 6 inches difference in the elevation of Lakes Huron, Michigan and Erie?

A Very much less. I ought to make that matter for Lake Superior a little clearer; that matter of the lowering due to Lake Superior is nothing permanent. It was simply holding up the water for a period, and then the natural outflow of the Lake Superior area is re-established; and when I say the natural outflow, the surplus waters of Lake Superior come down the St. Marys River, and the condition is the lower lakes get their proper amount of water from that time on.

Q. How long was that condition in existence?

A. Why the bridge piers went in in the latter eighties, and the Chandler-Dunbar dam in the early nineties. I do not remember the exact dates.

Q. Over how many years would you say that the effect was noticeable?

A. You are getting me into a pretty involved line of mathematics.

Q. Approximately; taking the latter period of eighteen years, how many of those latter eighteen years would you say were affected by the impounding of water in Lake Superior? Perhaps this paragraph in this report would answer the question substantially, the report of 1903 (handing witness same). Is that of any service to you?

A. That shows that the bridge piers and the—I do not know whether that term "other small streams" indicates the Chandler-Dunbar dam or not. It speaks of that between 1887 and 1892.

Q. Without reference to the actual number of years during which the elevation was affected by the impounding of water in Lake Superior part of that effect was observable during part of the thirty year period, and part during the latter period?

A. I could not answer that without extended figuring.

Q. Has the effect of that impounding disappeared at the present time; the effect on the elevation of Lakes Huron, Michigan and Erie?

A. I should say yes; I should say practically the effect had disappeared. But there is this to be said about that, Mr. Williams: The mean lake elevations will show some small effect coming from that.

Q. Whatever the effect of that impounding in Lake Superior was on the elevation of Lakes Huron and Michigan, in the way of lowering the elevation, the effect having now disappeared, may we reasonably expect that Lakes Huron and Michigan will rise to the former stage, so that they will regain the loss occasioned by that?

A. I testified I thought it had disappeared. It had, so far as the impounding of water in Lake Superior was concerned, it had regained whatever was lost by that.

Q. It has regained it?

A. I testified that was my opinion.

Q. In your opinion does that effect account for any portion of the rise in the elevation of Lakes Huron and Michigan for 1905-1908?

A. I could not answer that without extended computation; it is impossible. You are asking me to account for a rise in the lake levels or a lowering of the lake levels. We know that those things are occurring from year to year. I have attempted to state very plainly that the elements on which a determination could be made, the rainfall data, the evaporation data, of which we have practically nothing, and the inaccurate knowledge of the ice conditions in the outflow rivers, all that data is necessary.

Q. I am not asking you now, Mr. Shenehon, for an answer as to the exact effect in inches or tenths of a foot. I would like to know whether or not in your opinion any part of the rise in the elevation of Lakes Huron and Michigan from 1905 to 1908 is due to the fact that the effect on the elevation by the impounding of water in Lake Superior has disappeared; not as to the extent of it, but whether it does to any extent account for it?

A. I should not wish to answer that without an extended computation. The conditions at Sault Ste. Marie are rather involved; the power canals, tapping the lake, and the compensating works having been put in on the Canadian side, so that you are getting into a pretty complex problem in that.

Q. Before leaving that subject, Mr. Shenehon, I understand that the situation is this: that the impounding of water in Lake Superior did in your opinion have an effect on the elevation of Lakes Michigan and Huron. That effect has disappeared but you do not desire to express an opinion one way or another as to whether or not the cause having disappeared that it would not have any effect at all on the elevation of Lakes Michigan and Huron?

Mr. Wilkerson: He limited it to certain years. Your question was for a certain period, 1904-1908.

Mr. Williams: Since the effect of the impounding has disappeared.

Mr. Wilkerson: He said with reference to those years, he would not want to express an opinion without computation.

Mr. Williams: The reason I have asked the question is because I want Mr. Shenehon to have an opportunity to explain if he wants to. If he desires to leave it just as it is I am satisfied.

Mr. Wilkerson: Would you prefer to make that computation and answer the question later on?

Mr. Williams: This is not a matter of computation.

The Witness: I should prefer on that whole matter to await a computation. Whether or not the effect disappears is a thing I am a little bit in doubt of, as I think it over; and how long it might take for that effect to disappear.

Q. Then you would prefer to modify your answer?

A. I do not like to give an opinion on that right off the bat; it is rather a complex thing.

Q. Then do you want to modify your answer as to the effect having disappeared?

A. I should like to reserve that.

Mr. Wilkerson: He said he preferred to reserve the whole question.

The Witness: Yes; it is a complex question. If you are temporarily impounding water in Lake Superior, St. Marys River is supplying Lakes Michigan and Huron with less water, and the St. Clair River is carrying the water off all the while, so we are very certain to have a lowering effect due to that. Now, after Lake Superior is at a higher plane and pours out simply its normal surplus of water, I think it is very certain that Lakes Michigan and Huron would re-establish themselves as would also Lake Erie and Lake Ontario, which would also be lowered during the impounding or sub-

sequent to it. But that matter I should like to reserve and think over. I think that is the truth.

Q. And if it has not yet occurred it will at some time; that is if the effect has not entirely disappeared up to this time, it will disappear at some time?

A. Yes.

Q. Now I will ask the question propounded some time ago with reference to the fluctuations of Lake Erie: Do they depend entirely upon those of Lake Huron?

A. No; the St. Clair River supplies the largest portion of water—the St. Clair River, Detroit River, supply the largest portion of water for Lake Erie; that is the prominent supply.

Q. But there are fluctuations of Lake Erie independent of fluctuations in Lake Huron and Lake St. Clair?

A. Yes, small fluctuations.

Q. What would be the effect on the discharge of the St. Clair River of a rise of Lake Erie?

Mr. Wilkerson: Huron remaining stationary?

Mr. Williams: Huron remaining stationary?

A. It would have the effect of retarding the outflow of the St. Clair River.

Q. Then the effect of a fall in Lake Erie would be what?

A. It would have a tendency to accelerate the flow.

Mr. Wilkerson: Huron remaining stationary?

Mr. Williams: Yes.

Q. Now, in determining the increment for the St. Clair River, is the elevation of Lake Erie taken into account?

A. It was not considered except as the observations extended over a long period. It is assumed that the conditions for that period were normal. I may state further that during the seasons of 1899, 1900, 1902, Lake St. Clair which governs by its backwater effect the outflow in the St. Clair River to the extent that I have already testified was at a normal condition; and to that extent both Lake Erie and Lake St. Clair have been considered in establishing the rate of outflow from Lake Huron, or the increment.

Q. Do you consider that the relative positions of Lakes Huron and Erie, during the time of the discharge observations, from 1899 to 1908, was representative of the continued relations of the two lakes?

A. The relation of Lake Huron to Lake Erie during 1899, 1900 and 1902 (and that should be reserved to the open season when discharge observations were being made), was in accordance with the relations of those two lakes, as shown by the

terms of years from 1875 down. An attempt was made, and I think successfully, to make the increment rather favorable to the contentions of the Sanitary District in this case in the Plate Exhibit 1 by making the increment there the greatest, and when I say that, I mean the year 1901 was excluded in that determination of the increment. I should say that the line as drawn to the observations, is the computed line excluding the year 1901. And when I say the line is set down favorable to the contention of the Sanitary District, in my opinion I believe the increment is smaller and the effect is greater, as I have already testified; and the reasons, I have given for it.

Q. At the time that these discharge observations were made which form the basis of Exhibit No. 1, the level of Lake Huron and of Lake Erie was below normal, was it not; that is below the mean?

A. For the St. Clair River, the observations between the years 1899 and 1902, inclusive, are from Lake Huron elevation 579.65 to 581.39, a range of 1.74 feet.

Q. And the mean elevation is what?

A. The mean elevation of Lake Huron is 581.32.

Q. That mean is for the entire period?

A. That is from 1860 including 1908, I believe. That is the upper limit of the observations cut the mean lake level but did not extend much above it.

Q. What was the elevation of Lake Erie during the time of those observations, as compared to the mean elevation?

A. I have not that data for the seasons of the year. What I gave you there is for the times of the observations, the limits of the observations.

Q. That is for the months?

A. No, I mean those were the actual lake observations, during the observation.

Q. During the actual period?

A. During the individual measurements; the highest measurement was 581.39 and the lowest 579.65.

Q. Would you be able to state whether or not Lake Erie was above or below normal at the time these observations were made?

A. On the St. Clair River you are speaking of Mr. Williams?

Q. The observations on the St. Clair River, yes.

A. During 1900, Lake Huron shows elevation of 580.46; during 1899 (and this is the open season) Lake Erie is at

572.11; during 1900 about the same; during 1902, it is 572.20, and the mean level taken as 572.61 is the latest, and that indicates that as a mean of the season, the lakes were below the mean lake level; but for the individual months, perhaps that should be tabulated and put into the case, if you care to have it, what the elevation was for the individual months during the discharge observation.

Mr. Wilkerson: Have not the figures, which form the basis of such a computation been identified here?

A. I think so.

Mr. Williams: Assuming, Mr. Shenehon, that at the time of making these discharge observations, the relative elevation of Lakes Huron and Erie was normal; Lake Erie is at an elevation below normal. Then assume that Lake Erie was at a normal stage of elevation, and that Huron was correspondingly higher, so that they maintained their relative elevations, what effect would that higher elevation of Lake Erie and corresponding higher elevation of Lake Huron have upon the discharge of the St. Clair River?

A. Why, the discharge of the St. Clair River would be greater for a higher stage of the two lakes where they maintained their relative relation.

Q. And the increment would be larger, would it not?

A. As a rule the increment increases somewhat for higher stages.

Q. Would you be willing to express an opinion, Mr. Shenehon, as to whether or not the relations existing between Lakes Huron, St. Clair and Erie for the periods of your observation represent average conditions that may be expected to prevail in the future?

A. It depends upon what the future contains.

Q. Under normal conditions?

A. You mean assuming larger diversions at Chicago, for instance?

Q. Assuming natural conditions?

A. I see no reason why they should be largely different.

Q. Was the effect of the storage of water in Lake Superior present at the time these observations were made?

A. That whole line of questions I would rather reserve. Speaking off hand I should say some effect was present at that time, but not to an extent to interfere with the relative elevation of Lakes Michigan, Huron and Erie within such limits as we expect them, one to follow the other.

Q. You mean the relative elevations of Huron and Erie?

A. Huron and Erie, yes.

Q. Assume that the decreased difference of level between Lakes Huron and Erie, which during the past nineteen years has been on an average of about 6 inches less than that during the preceding thirty years, is due to temporary causes; and that Lake Huron may be expected to rise relatively to Lake Erie to the old average difference. If that should occur, what in your opinion would the effect be on the discharge through the St. Clair River?

A. That is, you want to get the effect of the discharge on the St. Clair River for the conditions governing the latter period of the two as compared with the former period?

Q. No. It is a hypothetical question. The last nineteen years shows that the difference in elevation between Lakes Huron and Erie is six inches less than it was during the former period of thirty years. Now, assume that that change in difference of elevation is a mere temporary change, and that in the future the difference in elevation between the two lakes will go back to what it was during the first thirty years, be six inches more than it is at present; what would the effect of the resumption of that difference of elevation be upon the discharge through the St. Clair River?

A. You assume that both Lake Erie and Lake Huron go up to the former elevation, elevation of the period of the earlier thirty years?

Q. Yes; irrespective of their both going up; if they resume the difference of elevation?

A. Of course, my belief is that the difference of elevation is practically now what it was before. When you take into consideration the stage or the elevation of the lakes, that when one goes up a foot the other goes up .7 of a foot, so for higher stages you get a bigger difference in elevation.

Q. Take my question as a hypothetical question: Assume that during the past nineteen years the difference of elevation has changed so that there is six inches less difference?

A. At a fixed elevation for Lake Huron or for Lake Erie?

Q. Take the elevations of Lakes Huron and Erie as they were during the thirty-year period; and their relative elevations?

A. Do you want me to give a quantative result what the discharge would be in cubic feet per second for a given lake elevation?

Q. No, would it be more or less?

A. For the higher elevation of the lakes as they were in the earlier period the discharge would be somewhat higher.

Q. Irrespective of the elevation of the lakes, would a resumption of the difference in elevation to the same amount as existed in the former period of itself have any effect upon the amount of the discharge?

A. No substantial effect; perhaps one per cent.; that is, I computed that Lake Erie was within .12 of a foot, as I recollect it, of where my computations for relative elevation would bring it. And I have shown in other places in my evidence that the backwater coming up from Lake Erie was somewhere in the neighborhood of 80 per cent. and that one-tenth change on Lake St. Clair, that is, an increase of one-tenth there, would have about three-quarters of one per cent. effect on the discount; two-thirds of one per cent., I think that was, so that it would be well within one per cent. I should think any change due to abnormal relations between the two would not vary more than one per cent.

Q. Do you know what the average slope between Lakes Huron and Erie was during the period of your observations?

A. Not in detail. The records that we have will show that.

Q. Assume that Lakes Erie and Huron have a certain difference of elevation during the thirty-year period. Assume that for some reason, temporary in its nature, the relative elevations changed, so that the difference in elevation is six inches less during the latter period of nineteen years. Then assume that the temporary conditions causing that change in difference disappear, and that either Lake Erie goes down or Lake Huron goes up, either one, so that the difference in elevation is six inches more than it is at the present?

Mr. Wilkerson: That is, as I understand it, you mean this: does the fact that Lake Erie is relatively higher have any tendency with reference to the level of Michigan and Huron, is that it?

Mr. Williams: No.

The Witness: You have the question as a matter of differences. If you state specific elevations for Lake Erie and Lake Huron, the difference you are getting at would show, and I could understand the question. But if the difference is gotten by Lake Huron being six inches higher up, the effect in the discharge is not the same as if Lake Erie was six inches lower down. By lowering Lake Erie you can increase your difference, or by raising Lake Huron.

Q. I am not asking for any figures in cubic feet per second.

Assume Lake Erie remains stationary, and that in order to get back the difference in elevation between the two, Lake Huron rises six inches, what would be the effect on the discharge through the St. Clair River and on the increment?

A. I think I have an answer to this now. I would make this reservation in regard to things that I figure in this way, that in case a refiguring of it shows me that I was in error as I figure it now, I may correct it in the record.

Mr. Williams: There is no objection to your making any correction that you see fit, if you find that you have made an error in your figures at any time.

The Witness: For a rise of half a foot or six inches in Huron, if Lake St. Clair should come up its proper relation also, the change in discharge would be 12,000 cubic feet according to our curve; that is, half a foot multiplied by 24,000, or by 23,820 more correctly; and on account of less backwater effect in Lake St. Clair, we would add 1,780 cubic feet to that, making it 13,780 feet, instead of 12,000 feet.

Q. What effect would that have on your increment?

A. If that relation should be maintained constant, the increment would be increased.

Q. How would that influence the effect of the diversion at Chicago?

A. It would indicate a less lowering of Lakes Michigan and Huron, should that condition become permanent.

Recess to 2 o'clock p. m.

June 5, 1909,
2 o'clock p. m.

Cross-examination of Mr. Shenehon resumed.

Mr. Williams: Mr. Shenehon, in the report of the Chief of Engineers for 1903, at page 2813, and continuing to 2817, appears a report upon the discharge measurements of the Detroit River. Were those measurements made under the direction of the Lake Survey?

A. Yes.

Q. And the tables shown on pages 2816 and 2817 are taken from original files on file in this office? Those reports are taken from data in this office?

A. I presume so. I have never personally seen the data. That was compiled before I was Principal Assistant Engineer; and I presume it is in the office.

Mr. Williams: Without offering in evidence the report, I would like to have the record show that this report by Mr. Blanchard, junior engineer, in the report of the Chief of Engineers for 1903, at pages 2813 *et seq.*, will be referred to by us hereafter.

Q. Did you ever examine these tables?

A. Not carefully. The discharge measurements of the Detroit River are not regarded by this office as having any great weight. The conditions were rather difficult.

Q. What would you say as to the degree of accuracy that was obtained in the making of these discharge measurements in the Detroit River?

A. I do not know. I have never investigated that matter of the Detroit River; I have never thought it essential. I have always thought that the discharge of the St. Clair River governed this whole proposition; and that Lake St. Clair could simply be considered an enlarged portion of the St. Clair River, and therefore the discharge measurements in the Detroit River were of little moment.

Q. If they were accurately made, they would be valuable as corroborating the results obtained in the St. Clair River, would they not?

A. I should say not, because continuity of flow is not present. Lake St. Clair acts as an intercepting reservoir in there, in between, and it is not a continuous flow. It would not correspond to two sections on the St. Clair River, as, for instance, in the Niagara or the St. Lawrence.

Q. What were the conditions which you referred to as not having been satisfactory conditions under which these measurements were made?

A. Slow current, small slope between Lake Erie and Lake St. Clair; the liability of Lake Erie to change during the discharge observation, so that the change in slope was a very considerable percentage of the total head due to the difference of level between Lake St. Clair and Lake Erie, and the complex condition arising from separating the effect of Lake St. Clair's elevation on the discharge, and Lake Erie's backwater effect on the discharge. I think I should add to that, small range in the discharge observations; that is, the stage on Lake St. Clair, during the discharge observations.

Q. Have you any information that would lead you to believe that the results shown by these measurements were inaccurate?

A. Not as regards volume of flow at mean stage of the ob-

servation. I do not know anything about what the increment is, or what its value is. I have not studied the observations in detail.

Mr. Shenehon, is this a fair statement of the situation: that you consider the results obtained from these discharge observations will be of very little value to you in arriving at the conclusions that you seek to arrive at; but that you have no doubt of the accuracy of the actual discharge, at the time of the measurements?

A. I have stated that I think the conditions were such that the measuring of the discharge becomes more difficult there.

Mr. Wilkerson: It is more difficult in the Detroit than in the St. Clair River?

A. Oh, very much, yes.

Mr. Williams: So that the measurement itself is not as accurate, and even if it were fully as accurate, the results would not be as helpful to you in arriving at your conclusions, as they would be in the St. Clair River, where the slope is greater?

A. The weight of the observations in the St. Clair River is very much greater. Lake Erie is likely to change very rapidly, and where your original slope is about 3½ feet and Lake Erie comes up a foot, making it only 2½, you have a change of condition that is likely to come during a discharge observation. I have never myself thought the measurement of the Detroit River important; and I have never thought that we had any data that was very valuable. But I have never studied in detail the discharge observations.

Mr. Wilkerson: That is as you have studied the St. Clair and the Niagara and the St. Lawrence?

A. I have studied the St. Clair to some extent, and the Niagara and the St. Lawrence to a very considerable extent.

Mr. Williams: Is it possible for Lake Huron to vary without a corresponding variation in Lake St. Clair?

A. Temporarily, for an hour or two hours or three hours.

Q. During a period required for the making of one of your observations?

A. Yes. The effect of that, however, is that it is just as likely to go down as it is to go up, that is, Huron, with Lake St. Clair remaining constant, so any error that comes in from that source is self-eliminating in a series of discharge measurements.

Q. If Lake St. Clair should remain stationary for a period and a set of discharge measurements were made on the St.

Clair River with Lake Huron varying, would it be possible from such a series of observations to determine the increment of the St. Clair River due to the changes in Lake Huron uninfluenced by Lake St. Clair?

A. That is, Lake St. Clair remaining at constant elevation, Lake Huron varies.

Q. Lake Huron varying?

A. Over a sufficient range—

Q. For a set of discharge measurements to be made?

A. Yes, your increment could be derived under those conditions.

Q. If from the observations already made on the St. Clair River a series of groups were arranged wherein Lake St. Clair was at a constant elevation for each group and Lake Huron was varying, would it be possible to determine the increment with change in Lake Huron independent of Lake St. Clair?

A. You mean following the process we actually have followed, without considering Lake St. Clair; taking into consideration the elevation of Lake Huron, the volume of flow, grouping?

Q. Yes.

A. I think so, yes.

Q. How would you do that?

A. Plat the discharge with respect to Lake Huron elevation; draw a line threading the platted observations. The increment then is the rate at which the discharge changes for each foot of change on Lake Huron.

Q. In your answer, do you assume one group or several?

A. In getting the increment?

Q. Yes.

A. A large number of groups.

Q. And do you assume Lake St. Clair to be at the same elevation for each group?

A. In constructing the chart, which is the exhibit?

Q. No, I mean in your answer now, as you have explained the method of determining this increment; do you assume that Lake St. Clair is at a constant elevation for each group, or a constant elevation for all the groups, that is the same elevation for the several groups?

A. As I understand the question, you ignored Lake St. Clair, paying no attention to what its elevation was.

Q. No. I say, you take a group of observations with Lake St. Clair at a constant elevation and Lake Huron varying.

Now in the different groups of observations, Lake St. Clair may vary, but it is constant through the several observations. Could you get an increment, determine an increment from those several groups, due to the change in elevation of Lake Huron independently of Lake St. Clair?

A. If I understand the question, it is equivalent to ignoring Lake St. Clair, just as if the river went over a cataract, and we were considering simply Lake Huron effect on the discharge. Am I right in understanding it in that way?

Q. My proposition was: Suppose we should group your observations into groups, wherein Lake St. Clair is constant for each group, of course different from group to group; and assume you would get a number of observations, I understand from your first answer that you could get an increment for Lake Huron for any position of Lake St. Clair by that process?

A. You mean out of observations already taken?

Q. Yes.

A. Or a supposititious lot of observations.

Q. No. I take it, if it were possible to get from your observations a series of observations in which Lake St. Clair was constant and Lake Huron varied—

A. By selection?

Q. —by selection, yes; you could then determine an increment for the St. Clair River with Lake St. Clair constant for that series of observations. I understood that to be your answer to the former question. Now what we were getting at was: if we took all such possible combinations in your observations and got a series of increments for each stage on Lake St. Clair, we could then determine a mean for the river in which the effect of Lake St. Clair would be eliminated, that is what I should assume?

A. I can't see that that process would be correct. If I understand it correctly, it seems to me that the increment is the increment shown with the conditions as they did exist.

Q. We would be assuming that these conditions did exist in this case. For instance, suppose that Lake St. Clair was at a certain elevation at the time that a group of observations was made, and it remained constant during that series of observations?

A. Yes.

Q. Lake Huron varied. From that group of observations, you would be able to determine the increment?

A. But it would be an abnormal increment. It would not

represent the conditions as we would meet them from week to week, month to month, and year to year.

Q. That would be a single observation and a single increment, determining it from one set of circumstances that might not recur again. But suppose that it were determined that immediately thereafter Lake St. Clair was at a different elevation when a series of observations was made, but it remained constant at that different elevation, and Lake Huron were constant, you could determine an increment for that condition of affairs also?

A. But that would be abnormal also.

Q. If you could get a series of those, each perhaps abnormal, would it be possible to get a mean increment from those several groups?

A. I should say if the individuals were abnormal and incorrect, the mean would not bring them correct as regards increments. That is, you are assuming a condition that is artificial, as regards the problem in hand. When Lake Huron rises, and the St. Clair River sends more water down into Lake St. Clair, Lake St. Clair rises because there is more water there. If Lake St. Clair is sending more water down on account of Lake Huron's rise, the supposition that Lake St. Clair would remain constant is rather—

Q. The St. Clair would not remain constant in that case, would it? From the reports of your observations, Mr. Shenehon, there are thirty-one observations where the elevation of Lake St. Clair is the same, and where in each instance the elevation of Lake Huron is different. Taking those conditions, they were natural conditions, were they not?

A. Natural, but temporary conditions, I should say; that is thirty-one out of how many observations?

Q. Thirty-one out of a series have fallen under that condition?

A. Out of two hundred or more?

Q. I do not know. As a matter of fact the majority of these observations fall into about ten groups; that is, would be included in about ten stages of Lake St. Clair?

A. Well, the effect of getting an increment in that way, which I regard as unfair and not applicable to the case we are dealing with, would be to get a larger increment, I should say. I should say it would make the increment larger, if you should consider it in that way. The proposition, as I see it, is to establish an increment which involves equivalent elevations of Lake St. Clair for Lake Huron elevations. That is

the state of nature, as I see it. Your proposition is, as I understand it, to establish an increment for a series of conditions that are not in a state of nature.

Q. They are all natural conditions?

A. That is, as a matter of fact, taking the open season for a number of months together, so that we can eliminate these little fluctuations which might be picked out of a series of observations, the condition is that when Lake Huron is at one place, Lake St. Clair is very close to another place; and when Lake Huron goes up a foot, Lake St. Clair goes up somewhere in the neighborhood of 66 per cent. of that amount. That, as the observations indicate, as the gage observations indicate, that is the relation holding between those two water surfaces.

Q. But suppose we did desire to obtain an increment based upon the variations in Lake Huron, and independently of the conditions in Lake St. Clair, how could we do it mathematically, now? Not as to whether or not it is going to do us any good after we have done that, or whether it is going to bring results that will be satisfactory to either of the litigants in this case; but the question is, mathematically how would you go about to do that?

A. There are three ways of doing it; one is to ignore Lake St. Clair entirely. Another way is to assume that it is at a fixed elevation all the while, and that Lake Huron varies. And the third way is to take note as to whether Lake St. Clair is occupying a normal position with respect to Lake Huron. If a series of observations covers a term of years, a long enough period so that Lake St. Clair holds an elevation with respect to Lake Huron that represents a state of nature, the increment derived is correct, as I see it. If on the other hand you hold Lake St. Clair stationary and move Lake Huron up and down, which I do not see is a state of nature, you get an increment, but I do not think it is a correct increment.

Q. We are not going into the question of whether it is correct or not; but would it be an increment based upon the variations of Lake Huron, without any influence being exerted by the conditions of Lake St. Clair?

A. No, Lake St. Clair's influence is present still ,although you keep it at the same elevation. What I mean is if you should take out Lake St. Clair and have a cararact there, you get your water flowing through your river, therefore Lake St. Clair is still exerting back water influence although you hold it stationary.

Q. Suppose, Mr. Shenehon, that we were to construct some sort of controlling works by which we could see to it that the level of Lake St. Clair did not vary one hundredth of an inch, and then we desired to obtain the increment based entirely upon the variations in Lake Huron, wouldn't the method that you have suggested be the method of obtaining that increment?

A. Yes.

Q. Now suppose, on the other hand, that we were able to and did succeed in maintaining Lake Huron at constant and unvarying elevation, and at the same time the elevation of Lake St. Clair should vary, what would be the method of obtaining, in that event, the increment of the St. Clair River caused by variation in the elevation of Lake St. Clair and unaffected by Lake Huron?

A. Plat your observations and draw the line.

Q. If an increment were obtained for the St. Clair River, first based upon the varying elevations of Lake Huron unaffected by the elevation of Lake St. Clair, and secondly by the varying elevations of Lake St. Clair unaffected by Lake Huron, would it then be possible by establishing the relation of changes of elevation of Lake St. Clair and Lake Huron, to compute an increment for the St. Clair River embracing the influence of both lakes?

A. Yes; that is, you get in the former case the influence of change of Lake Huron, and your backwater effect due to change in Lake St. Clair, and by combining the two you do get your equation, write out your equation—that is right.

Q. Would there be anything unfair about that method?

A. No, not provided you take both of them. If you took either of them individually, you have got an unfair result, but is is the combination of the two that gives the proper result.

Q. An increment obtained in that way would be likely to be at least approximately correct?

A. Yes.

Q. And the statement that you put in the record, Mr. Shenehon, a few months ago, that that method of obtaining increment would be unfair was based upon a misapprehension of the entire method?

A. I will repeat that and emphasizing it, taking—

Q. That was only a part of the method?

A. Taking either half by itself and not considering the other part, the thing is unfair; and that was my under-

standing of your proposition; not the conjunction of the two.

Q. You did not understand at that time what the proposition was in its entirety?

A. I had not surrounded your conception.

Q. Suppose that the observations made by you of the discharge of the St. Clair River showed that with Lake Huron at a certain elevation, and Lake St. Clair at a certain elevation; those same elevations prevailing at the time of different observations, and that the discharge as found from these observations varied from 600 to 8,600, with no change in the elevation of Lakes Huron and St. Clair, to what would you attribute the variation in discharge?

A. What do you mean by variation of from 600 to 8600?

Q. 600 cubic feet to 8600 cubic feet?

A. You mean from the mean of the lot?

Q. No, two observations, the difference between them, the stages of the two lakes being the same, they are that much apart?

A. That is how many observations?

Q. Take a series of them where it appeared that Lake Huron and Lake St. Clair were at the same elevation?

A. Half of the divergence, 4300 is a little over 2 per cent, and a divergence of 2 per cent from the mean is not an extraordinary error of observation.

Q. I ask how you account for it?

A. It is what is known as error of observation. The river might have been not in equilibrium at the time of the observation.

Mr. Wilkerson: That is it would make a difference whether you got it with an upward swing or downward swing, is that it?

A. Lake Huron during that observation might have gone up and come down again, and the mean elevation might be the same as for a case where Lake Huron went down and then came up. The direction of the travel of Lake Huron during the discharge measurements might have some influence on it. Lake Huron might be rising during one of the observations, and falling during the other; and while the mean elevation of Lake Huron is the same, the effect on the river is different. And Lake Huron is as likely to be rising as it is to be falling. In a large number of observations, the effect of this is eliminated.

Mr. Williams: If it appears from these observations that the variation in the flow of the St. Clair River amounting to

two to three thousand cubic feet per second might go unobserved, do you know whether that is true or not?

A. You mean that the error of observation might be as much as two or three thousand cubic feet in an individual observation?

Q. Yes.

A. I should say yes.

Q. If that be true, I wish you would explain to us why you think that a flow of 4,000 cubic feet, and the effect of a diversion of 4,000 cubic feet at Chicago, could be so accurately arrived at as to enable you to say it will lower the entire lake level two inches or more?

A. The question as I understand it is, if in an individual observation the error of observation may be as great as two or three thousand cubic feet per second, why our work is not so inaccurate that we cannot get the effect of influences of four thousand or five thousand at Chicago. I say that the error of a single observation is that one is large while another is small. This is what is known as a compensating error, and enters into all forms of observations, and it is eliminated in the large number of observations of a series.

Mr. Williams: I would like to have the record show that we will offer in evidence at the hearing tables 9, 10, 11, 12 and 13, appearing upon pages 2878-9 of Appendix FFF of the Report of the Chief Engineers for 1903.

Mr. Wilkerson: Are you going to offer them without any further explanation as to the manner in which they were prepared or the conditions under which they were made?

Mr. Williams: Mr. Wheeler testified as to the probable degree of accuracy of the rainfall observations and how the rainfall observations were made. And several of your witnesses have testified that they thought they were not reliable, but they were the best they had; and we want just what there is of it.

Mr. Wilkerson: Of course this is not the time to object to their reception in evidence, nor do I want to be understood as imposing on you any hard rule with reference to making these tables competent. But I suggest that if any particular tables relating to rainfall are to be offered in evidence there should be some evidence with reference to the compilation of the particular table which is offered. And I will say we would be very glad to find out who the witness is and make it easy for you to put in that testimony. I do not wish to be put in the position of consenting that these tables are to be re-

ceived as an accurate basis for computations which may be made upon them.

Mr. Williams: I am not asking counsel to stipulate that when these go in they mean one thing or another. The witnesses have testified as to what degree of accuracy they thought attaches to these tables.

Mr. Wilkerson: Mr. Wheeler's testimony is not now fresh in my mind. If in his testimony he has covered the manner in which these tables were prepared so you think that is all you would want as making them competent, there would be no necessity for recalling him on that point. I merely suggest that a table, of course, is the statement of a result which has been derived through a certain method; and I should want, and I would think you would want, the record to show the manner in which these tables had been compiled. You are not able to throw any light on that at all are you, Mr. Shenehon?

Mr. Shenehon: No.

Mr. Wilkerson: It is knowledge entirely outside the scope of your work; a matter with which you have had nothing to do. Am I correct in that?

Mr. Shenehon: Yes.

Mr. Wilkerson: I will say this, Mr. Williams: It is perfectly obvious it will be necessary for us to return, and I make this suggestion about those tables: If there is anything that occurs to you that you would want in the record to make them competent when they were offered, I would be very glad to have the witness present who can testify with reference to them. The matter having been suggested at this time, I did not want to have you understand that I was not going to object to these tables when offered at the hearing, because I think I shall object to them.

Mr. Williams: On the ground of their not being material, not on the ground that we have not laid the proper foundation. If you are going to object because the proper foundation has not been laid, we will have to call Mr. Wheeler and go into all the details as to how the tables were prepared.

Mr. Wilkerson: There are tables and tables. A table may be prepared from one set of observations which is perfectly competent, that is evident. I think that is true with reference to these discharge observations. As to the rainfall tables, I do not know how much is based on actual observation and how much is conjecture.

Mr. Williams: They are all based on actual observation,

but as every one of your witnesses testified the observations were at such different points—

Mr. Wilkerson: There was such a vast field to be covered, the points are so far apart, that the result which is reached is of necessity subject to a very large correction on account of error.

Mr. Williams: That is a matter to be addressed to the court as to the weight which he will give to the evidence, not as to the competency of the evidence itself.

Whereupon the hearing was adjourned to Tuesday, June 15, 1909, at the hour of ten o'clock, A. M.

Detroit, Michigan, June 15, 1909.

Parties met on the above date pursuant to adjournment.

WILLIAM LIVINGSTONE, was recalled for further cross-examination by Mr. Williams and testified as follows:

Q. Of the six hundred boats, approximately, mentioned by you as being owned by the members of the Lake Carriers' Association, you testified that about 70 per cent of them would be affected by a lowering of the water at these critical points?

A. I said so, approximately, yes.

Q. And then the question was as to what percentage of that 70 per cent would be affected by a change in levels of the Detroit and St. Clair Rivers?

A. Well, if you will pardon me, suppose we start with this as a basis: I find in looking over our list that we have had some changes. We have altogether 598 boats in our Association, and of these 90 are tugs and lighters, which we do not class with the others. That would be 598; I told you 600. We have had some changes, one or two losses, one or two withdrawals and some additions, so the result is today, the total number of boats we have in our Association is 598. Of these 90 are tugs and lighters; they are harbor tugs, and they are a class by themselves so that they are not affected at all. That leaves 508 steamers and barges. Some of these 508, a few, are tow barges towed behind the large vessels so that the 508 is really what we use for commercial purposes, trading purposes. The tugs, you know are used entirely for towing.

Q. Of that 508, does your estimate hold good, that is that there will be about 70 per cent affected by a change of level?

Mr. Wilkerson: If he has those figures compiled, I suggest that he might go ahead and give a complete compilation.

The Witness: Just repeat your question.

Mr. Williams: Of the 508 boats and barges in service owned by your Association, how many would be affected by a change such as has been discussed in this case in the levels of the great lakes at the critical points?

A. We have of steamers of 22 feet and over, 322. We have 22 sailing vessels. What I mean by sailing vessels are the barges that are towed behind; 322 steamers and 22 sailing vessels. That makes a total of 344. Mr. Marr, who is secretary of this Association, at my request tabulated the figures for me. Of steamers of 19 feet to 21.9, we have 76, and tow barges 10, that makes 86. That would make a total of 430 boats in our Association that would be affected if they were loaded to their full depth, we figure, by any change in the water, for instance at the Sault Locks or at Ballard's reef. That would make a total of registered tonnage of 1,837,000 tons; perhaps to be accurate it would make 1,837,737 tons. Then you asked me in addition to that about the percentage of vessels that traded from one lake to another.

Q. Yes. Have you prepared an answer to that?

A. You can't give that absolutely accurately. At the Sault of course the government officers keep an accurate account of the tonnage. In 1908, the passage of registered vessels at the Sault was 13,908. That is net tons. Everything at the Sault is computed on the two thousand pounds basis, net tons. That was 41,390,557 tons. That made the average tons per trip 2,976. Between Lake Superior and Lake Michigan (that was one of the questions you asked) there were four and a half million tons carried, or to be accurate 4,503,055 tons. Taking the average of 2976, and that is the only way we could get at it, per trip; that was the average of what passed the Sault, you understand; in other words there were 13,908 tons passed the Sault net; that amounted to 41,390,000. That made the average tons carried per trip 2979. So, take the four and a half millions of tons, there was 1513 trips made; and at 2976 tons per trip, that made the percentage of trips to Lake Michigan 10.9, or call it 11 per cent. Then between Lake Huron and Lake Superior there was 1,651,000 tons of freight carried, and averaging that on the same basis, between Lake Huron and Lake Superior, say 2976 tons per trip, that would make 555 trips. That would make the percentage of trips 4 per cent, that is from Lake Huron to Lake Superior. Then

you take between Lake Superior and Lake Erie—that is Lake Ontario inclusive, because what goes to the lake, some of it goes through the Welland Canal, there were 35,236,482 tons, and on the basis of 2976 tons per trip, that is 11,840 trips.

You want to clearly understand in giving this, this is not confined to the Lake Carriers. This takes everything in, no matter how little or big; everything that is in commission. These percentages are not confined to the Lake Carriers' Association because, although the largest tonnage on the lakes is in our Association, there is myriad of small boats that do not belong to the Association. Between Lake Superior and Lake Erie we have 35,236,482 tons; dividing that by 2976 tons per trip would make 11,840 trips. That would make the percentage of trips from Lake Superior to Lake Erie 85 per cent. I believe I testified before it would be approximately about 80 per cent. It seems to exceed that.

You have got to bear in mind, so you will get it intelligently that in making these averages there is a large number of small hookers you know, running up to a large amount, that are not in our Association. For instance the lumber carriers are not in our Association at all and a great lot of others; but all the large modern boats are in the Association; our percentage is very large.

Q. You testified, Mr. Livingstone, that you were getting out a printed list of all the boats in your Association?

A. Yes.

Q. Has that been brought out yet?

A. Mr. Marr tells me that will be out day after tomorrow. It is in the printer's hands.

Q. What is the name of the publication? Does it have any special name?

A. Just a list of vessels having membership in the Lake Carriers' Association; gives a list of all those. We will be glad to furnish you a copy.

Q. Is there any authoritative publication giving the names and dimensions of all the vessels now plying on the Great Lakes?

A. Oh, yes, the Commissioner of Navigation has a report which shows it in full.

Q. Is the Blue Book of American Shipping also an authority?

A. The report is made out by the Commissioner of Navigation in the United States, Mr. Eugene T. Chamberlain.

Q. And that Blue Book is considered an authoritative publication?

A. Oh, yes, it is supposed to be the—

Q. You gave us very briefly the other day your experience as a navigator of the Great Lakes. Will you give us a little more in detail your own experience, when you first became interested and in what way, in lake navigation?

A. I think that I first became interested in vessels, I won't be sure whether it was in 1866 or 1867; it was one of those two years. I would have to look back and see. And I became interested by buying the controlling interest in a tug called the John S. Noyes, which was a Canadian tug. I bought a couple of barges; I wanted her at that time for bringing wood down from Bear Creek, or as we call it really the river Sidney.

Q. And that was your first experience as a vessel owner?

A. That was my initial experience as a vessel owner, yes. I remember thinking I was quite a—

Q. Just go on from that and indicate the progress made by you in your career as a vessel owner?

A. We traded with her that season. That was the first boat I was interested in and consequently I happen to remember it more particularly than some others very much larger. I remember thinking, taking her up across the flats and down again, occasionally thinking I was quite a man. That was the start.

Q. Just sketch the history of your career?

A. Well, that would be rather difficult. I have been interested more or less ever since, one way and another. There was at one time here on the lakes—it is hard to explain unless you throw a little side light on it—there was a time here for instance in 1866, 1867, along about that time you know, that on the Great Lakes here 93 per cent of the tonnage was sailing vessels, and less than 7 per cent steam. You see it has become a regular transformation scene since that time because while 93 per cent of the vessels on the lakes at that time were sailing vessels and 7 per cent, less than 7 per cent were steam, today, for instance, all the figures have been changed. I think the figures if accurately taken would show about 96 per cent steam and about 4 per cent sailing vessels, and in those sailing vessels I include the barges that are towed behind, the steam barges.

Q. You are a considerable owner of lake vessels at this time?

A. I am interested more or less, yes, sir. What I was going to say was that I kept branching out. My business was on the dock, naturally would be at that time; and I think I was at that time one of the largest tug owners on the lakes here. The vessels at that time, on account of their being sailing vessels, there was a very large number of tugs used for towing vessels through. All the vessels at that time, running along down until steam began to supplant sailing vessels were all towed through the rivers. We used to build large heavy tugs, not like these little harbor tugs; and we would go away outside, way up on Lake Huron; sometimes go as far as the Straits to get the vessels; depending on whether business was dull or not, and we would tow them through the rivers. None of these vessels you know expected to sail through the rivers themselves; they were all towed from Lake Huron or Lake Erie, towed through the St. Clair River, Lake St. Clair and the Detroit River. And we had an association here in 1869, of which I was the treasurer, practically the manager of it. We found that we had more tugs than sufficient to do the business. We had some, I don't remember forty-five or fifty tugs, so we found that we had overstocked the market. So we rather pooled our issues that way; laid up the boats that we didn't want and just kept the number sufficient to do the work economically. Then as steam kept supplanting sailing vessels as the years rolled by, the demand for tugs became less all the time. I then became interested in steam barges and one thing and another.

Q. Very briefly stated, you started as a very small owner of lake craft?

A. Yes, sir.

Q. And you have grown to become one of the largest and most influential lake owners?

A. Oh, no, I do not say that; I do not say that.

Q. I am saying it.

A. Not as an owner, no, because there are some very large fleets on the lakes. For instance you take the Pittsburg Steamship Company, they have a hundred boats.

Q. Then I will withdraw my question, if I did not state it accurately.

A. I have attained more prominence, perhaps, in this way: not so much as being an owner, though I am interested in a number of fleets and all that sort of thing, but I have attained more prominence perhaps on account of my position as president of the Lake Carriers' Association.

I should have said during this time too I represented the Western Transportation Company here, a line of steamers owned at that time not by the New York Central; they did not own them then. They had a line of a dozen steamers and half a dozen passenger boats. The passenger boats ran between Buffalo and Chicago, and that is now called the Western Transit Company; now belongs to the New York Central Railroad, but at that time we ran under contract with the New York Central Railroad, so I handled these boats here as agent, represented them.

Q. Let me ask you this question: What would you say as to the opportunity presented at present for a man to start out with the same amount of capital that you had in 1866 or 1867 and alone achieve the same success that you have achieved, during that period?

A. Well, I have not said anything about achieving success, myself.

Q. I have considered it success, and assuming I am right in saying you have been a successful man, what are the opportunities today for a man to start out along the same lines, with the same amount of capital that you had at that time, and achieve the same degree of success?

A. That is a hard question to answer.

Q. Would you say a man could do it as easily now as you did then?

A. No, sir, oh no, you can readily see that.

Q. Will you give us a reason?

A. For instance, when I first went into the vessel business, the Welland Canal had not been enlarged at that time. A boat going through the Welland Canal, sailing vessel, that carried 20,000 bushels of corn, was considered a good sized vessel. And at that time, on the gold basis, we built those vessels on the basis of about a dollar a bushel; that is the cost of building. The cost of building was much smaller. And they had to be built then like a dry goods box, almost, so as to get the greatest possible carrying capacity. It was no uncommon thing then for half a dozen men, you know, to own one of these vessels. When I just turned my majority, at the time I spoke of the Noyes—if my memory serves me right, and it is pretty accurate on that—I think I put $4,400 in that boat and I borrowed half the money to do it. And you take boats now, you can see what an evolution there has been from those canal schooners, built on a gold basis, on the basis of a dollar a bushel, costing $20,000. Sometimes half a dozen men

would be interested, and the captain very frequently had some interest in her. Now, you take that class of boats today, if you shingled the lake with them from Detroit to Chicago, you would not take them as a gift, because the more you had of them the worse off you would be. It has evoluted from that little vessel of $20,000 cost until you can't build a modern vessel, such as we build today short of from—depending on her size, having 7,500 tons, and then depending on how she is fitted out—from $275,000 to four hundred odd thousand dollars. So that you see the vessel business has gone into entirely different hands; strong hands, men of capital and men of means. It had to be so. So the chances for the small men of course—don't misunderstand me in one thing in these United States of ours, and I never leave the country and come back but what I think it is bigger than the last time. There is always room at the top for the fellow that works right, and always men make a success everywhere. But I mean the chances as a general proposition; a man could not start with a small capital as he could before. It does not take but a little you know, you take about three vessels and a man gets into a million dollars or over.

Q. Now you have referred to the Lake Carriers' Association; you are the president of the Lake Carriers' Association. Will you please state the nature of the organization?

A. You have the whole of it in that book I gave you. It will give it to you more clearly than I could. It states clearly and succinctly the object of the Association. Our constitution and by-laws are printed, and Mr. Marr will send you that when he sends the other; and that will give you clearly and succinctly the object of the Association, what it is organized for and its purposes.

Q. Does the same book give the names of the members of the Association?

A. No, we have a membership list separate from that.

Q. How many members are there in the Association?

A. I can't tell you; about seventy or seventy-five.

Q. And that membership consists of corporations and individuals, I assume?

A. Oh, yes. Nearly all boats are put in corporations, on account of the way they place stock. There are practically no vessels now—that is it is exceedingly rare where a vessel is owned by an individual; almost all form corporations.

Q. So that substantially the entire membership consists of corporations owning and operating fleets on the Great Lakes?

A. Yes. If there are but three or four owners even, they prefer to have it in corporations; it handles better every way. Lots of single boats form a corporation. If she costs $400,000, they will organize under the state law and have a corporation; then they are only responsible for their stock; limited liability.

Q. How many members would you say there are?

A. Mr. Marr suggests something to me which perhaps I ought to explain to you. It is not an uncommon thing for one member to represent five or six different fleets; he will be the manager of these lines. For instance in building up fleets, they will start and build one up of two boats, and then be organized under one company, call it anything, American Company, Atlas Company; then the business progresses and he wants to build a couple more boats. He may take in the same stockholders and add some others, so there will not be exactly the same stockholders, and they will call that a different company; so that in some cases we have one man who manages really four or five corporations, and he is the representing member in our association.

Q. How many members would you say there were in your association that own only one boat, for instance?

A. Not very many.

Q. Eight or ten?

A. I should think that would cover them. Of course there are some men that have one boat. There are one or two, two or three men that have one boat, that are interested stockholders in other corporations, you understand. A man may manage one fleet and be interested in a number of others.

Q. Is the United States Steel Corporation a member of your association?

A. No, not in that name; it is the Pittsburg Steamship Company. But the Pittsburg Steamship Company is really owned by the United States Steel Corporation, and the president and general manager of that line is Mr. Harry Coulby. It is a separate organization from the United States Steel Company. It is a corporation organized of itself and by itself, but all the stock is owned by the United States Steel Corporation.

Q. What is the next largest owner in your association? I assume that the company you have just mentioned is the largest owner of vessels?

A. Yes, they are the largest single owner, have the largest number of boats.

Q. What is the next largest owner?

A. The Gilchrist Transportation Company comes next.

Q. With what other interests is that company affiliated?

A. That is entirely an independent company. The Gilchrist Transportation Company is the second largest on the lakes, and that is made up of stockholders. I don't know how many stockholders they have.

Q. It is not affiliated with one of these large corporations?

A. No, it is entirely a vessel company, organized of itself and by itself.

Q. How many boats do they have approximately?

A. They have got sixty odd.

Q. Can you recall what is the next largest owner?

A. G. A. Tomlinson; they have several corporations in their fleet. You see that is owing to the fact that they are not the same set of stockholders; there will be some stockholders in all the boats, but not all the stockholders in all the boats.

Q. And they have about how many vessels?

A. Seventeen or eighteen; I am not sure which. I think Tomlinson has the largest average of any single fleet, the largest average tonnage of any single fleet on the lakes because all his boats are modern boats and all built within the—

Q. And the next largest is what, the Cleveland Company?

A. I think the Cleveland Cliffs is probably the next largest, they and the United States Transportation Company. It is kind of a toss-up between them. The Cleveland Cliffs boats are the Cleveland Cliffs Iron Company.

Q. The Pittsburg Steamship Company, how many vessels did you say they have?

A. They have got over a hundred. 108 Mr. Marr says. Perhaps it might throw a little side light on this tonnage business if I were to say this, if you do not object: that is you know all of the smaller class of vessels, as they go out of existence, you understand they are not replaced; they are passé; they are things of the past. In other words to boil it down, the transportation problem of today is all boiled down to one sentence and that is this: what will carry the largest amount of freight for the smallest amount of money. And experience has demonstrated that the modern fleets of boats that we are building now (I don't know what they will reach in the future) for instance a ten thousand ton boat we will say; it is impossible for one of the old type boats, and we used to consider a 3,000 ton boat very large, when the 10,000 ton boat will make money and pay a good fair dividend, it would be impossible

for the smaller boat, you know, to pay expenses. We have 10,000 ton boats, for instance that with the improvements in machinery, etc., the triple expansion engines, or quads (very few quads on the lakes), that will make the round trip now, for instance, carrying 10,000 tons of ore, and their consumption of fuel would be less than some boats carrying only 2,500 or 3,000 tons. And then with all the modern machinery and every conceivable attainable thing—and there are no boats in the world that are more modern and up to date than our modern freighters, so the result is that they only carry a few more men than the smaller boats do, and they are of the cheaper class of men, because, of course you have to have officers, masters, pilots, engineers, etc., on the smaller boats the same as you do on the larger ones. Of course on the larger boats they get a little more salary, but that is small as compared with the whole, so that the fixed cost per trip of a 10,000 ton boat as against a 3,000 ton boat is not at all in proportion, you understand.

Mr. Wilkerson: About what percentage of the freight is carried by these large boats about which you are testifying?

A. What proportion of the general freight of the lakes?

Q. Yes, the boats that you speak of as the modern boats?

A. I can only estimate that now.

Q. Approximately?

A. Oh, I think 80 per cent would be a low estimate.

Q. I am distinguishing between freight on boats of that kind and what you referred to a little while ago as the package freight boat?

A. The package freight boats, all of them on the lakes, as a rule, are owned by the railroads. For instance the Western Transit Company line, that is owned by the New York Central Railroad; the Mutual Transit Company line is owned by a combination of three or four roads; the Lehigh Valley Transit line, that is owned by the Lehigh Valley road. So that outside of the railroads, there are practically no package boats. You understand package freighters are built expressly for the purpose of being the connecting water link between lake and rail; they make an all-rail rate, and that would be a trifle higher than lake and rail; so that all these boats now are either owned or controlled by the railroads, and they are built for a specific purpose, different from ore and grain, that can be handled by elevators and big clam shells, and all that sort of thing. That freight has to be handled by hand. Of course they have engine hoists that hoist it out of the hold

of the boat, but it has to be trucked; you can't handle it like grain and ore. It has to be trucked in trucks by the stevedores on the docks; trucked off the deck of the boat on to the dock. But that percentage is very small; that is a special trade of itself.

Mr. Williams: And the package freight steamers would not be particularly affected by any slight change in the level of the lakes?

A. No, I should think not. I have not investigated that specially. You take such boats, in the fall of the year they would be affected surely. I will have to look that up.

Q. You did not take them specially into consideration, or have them in mind in arriving at your conclusion as to the effect on navigation generally?

A. No, I did not, although there are some of the new order of boats they are building that have a considerable freeboard. I do not make the statement positive, but I have an impression that some of those newer boats run as much as 24 feet freeboard; but I will not state that as a fact for I might be mistaken. I think some of them are moulded for 24 feet but I will not make that as a positive statement.

Q. During the early days of navigation on the Great Lakes, I believe you have already stated that very frequently the Captain or sailing master had an interest in the vessels?

A. Quite frequently. I do not mean in all cases but in many cases.

Q. What is the general rule now?

A. Oh, well, it is the exception and not the rule now, although we have Captains on the Lakes, quite a number of them, that own stock in some of the companies. Of course you take a line like the Pittsburg Steamship Company, no outsider could own stock in that because it is a line owned by the corporation itself; the stock is all held by it. It is just one of the connecting links, you know, in their line of business.

Mr. Wilkerson: Of course there is a vast number of stockholders who hold stock in the holding company?

A. Yes, the profits of that company, I don't know how they arrange it, but it is just a subsidiary company.

Q. United States Steel Company is a holding company; it owns no property outright, but it owns stock in a large number of subsidiary companies?

A. This is one of its subsidiary companies. I will say

one thing for the company: it is one of the fairest and one of the best managed steamship companies on the lakes, in its dealings with its employes and everybody else.

Mr. Williams: Q. Is navigation interfered with to your knowledge to any considerable extent by the swiftness of currents in the St. Clair and Detroit Rivers?

A. If I understand the question clearly, of course a vessel going up stream would not go so fast, of course, as a vessel going downstream. Assuming there is a two and a half mile current, three mile current—

Mr. Wilkerson: You mean the effect of the current in producing accidents.

Mr. Williams: I want to know whether navigation is interfered with; that is whether it is more difficult to conduct a successful business in navigation where you encounter swift currents and whether there are such currents now in the Detroit and St. Clair Rivers?

A. Oh, it is always more dangerous; the liability to danger is almost always greater for a boat navigating with a current than slack water because you can readily see why.

Q. What I am getting at is: is there a sufficient current during normal conditions now in the St. Clair or Detroit River to interfere with navigation to such an extent as to make it dangerous?

A. Well, that depends altogether on circumstances. I would not say it would make it dangerous because if a man has his boat under full control and supposing he obeys all the rules of navigation, it ought not to be dangerous. But like machinery human nature is fallible and where there is a current, there is more danger than where there is slack water, and the greater the current the greater the danger.

Q. Are there such currents in the St. Clair and Detroit Rivers?

A. Yes, in the rapids and in other places. Of course in the rapids that is a dangerous spot, because you take a boat coming down a rapid, if it is meeting another boat, and there is danger of collision, she can't stop and back there, cannot control herself; whereas if it were slack water, supposing the Master or Captain desires to stop and back, and back her strong with the whole power of his engine, he may not be able to back her there where he could control her without any difficulty whatever in slack water, so a current is always more or less dangerous.

Q. Would you consider an increase in the current in the

St. Clair River or in the Detroit River objectionable to the interests of navigation?

A. Yes, sir, I would. May I say just there, there is one reason why we are constantly fighting for double channels, so that boats won't meet each other in the rivers.

Q. How swift would you say a current would have to be, to be a dangerous current?

A. I should think a four mile current would come under the head of a dangerous current, because in case of danger of collision or anything of that kind, with the difficulty in controlling, backing and stopping, you can readily see that coming down stream with her own way and the way of the current, it takes a great deal more power to stop. The boat going up stream, with the current against her she can stop very quickly, or if it was slack water. So just to avoid that very thing we have been striving, on account of the great increase in the tonnage on the lakes, which has grown by leaps and bounds the last seven years, we are trying as far as practicable to get double channels all the way up the rivers. When we get the so-called Livingstone channel down here completed, we will have a double channel there. We expect the Canadian Government to build another channel, at least we are hoping so, and from the assurances I had the last time I was at Ottawa, I think we will get it in the near future, on the Canadian side of Fighting Island; that is the Canadian island down the river here. And up in the St. Clair River, we are making double channels all the way up there.

Q. Do you know at what points there is a current substantially equal to four miles an hour?

A. The current in the St. Clair Rapids abreast of Port Huron, say from Port Huron running up to Fort Gratiot, my impression is—I do not speak by the card—my impression is that current is about six miles an hour, yet I am not positive about that. It varies a little; they used to call it seven, but that is an over statement I know.

Q. Are there any other points where there is a current of that velocity?

A. No, not on the rivers here. I do not know of any place on the Sault River that has that current, with the improvements.

Q. Suppose the channel were 21 feet deep and 500 feet wide, would it then be objectionable to have the current increased?

A. I would have to turn you over to the engineers on that. I could not figure out the difference in velocity.

Mr. Wilkerson: I wish to note an objection to this line of cross-examination, on the ground that it is not proper cross-examination of this witness, and on the further ground that the question of the determination of the modification of the current in navigable waters of the United States is one exclusively for determination by the government itself.

Mr. Williams: Q. I am just asking you, as one familiar with navigation, whether or not in your opinion, no matter what the current is today, in a channel 500 feet wide and 21 feet deep, whether you would consider it objectionable to increase the current?

A. Of course it is impossible under existing conditions not to have a current; but every foot, so to speak, that you increase the current, of course it makes navigation a little more hazardous; it is impossible to be otherwise.

Mr. Wilkerson: I assume my objection will be taken to apply to each question in this series with reference to current, without repeating it.

Mr. Williams: Yes.

Q. That would be true irrespective of the dimensions of the channel?

A. Oh, yes, that would be true. Of course the narrower the channel, the shallower the depth, the greater the danger would be. For instance you take a 500 foot channel and you have some obstruction, with our big vessels, a man would not have the room to put his helm to port or starboard and steer clear that he would have in the thousand foot channel. Another thing, the deeper you make the channel and the narrower you confine it, it stands to reason the velocity of the water would be greater. You have two men who can answer that, Mr. Randolph and Mr. Shenehon.

Q. I am speaking merely from the point of view of the practical navigator?

A. That is all I can talk from.

Q. I am asking you also as a practical proposition, and as an experienced navigator of the great lakes, which you would consider preferable, a 21 foot channel with a slow current or a 25 foot channel with a swift current, both channels having equal width?

A. You would have to give me some idea of the difference in the swiftness.

Q. Suppose the 21-foot channel had a current of a mile and a half an hour?

A. Yes.

Q. And the deeper current had a channel of say four miles an hour?

A. I would hate to tackle the four mile current; that is I would want double channels if I was going to tackle the four mile current; that is pretty swift.

Q. Well, take it two miles for the 21-foot channel, and 2½ miles for the 25-foot channel; which would you consider the best adapted to the needs of navigation?

A. If I had the money to build the boats, I would take the 25-foot channel.

Q. Assuming the present condition of navigation on the great lakes, which would you say was best adapted to the present navigable needs?

A. Oh, as we are situated at present, the 21-foot, about the 21-foot channel or thereabouts is the better channel at the present time. Why? Because you know a chain is only as strong as the weakest link in it; and it does not make any difference if you have a hundred feet of water outside, if you have only got say 19 or 20 feet in your harbors, because what governs the draft of vessels are the harbors in which you have to unload. Now, outside of the harbors, we can go to Congress, for instance, and if the engineers agree with us in our conclusions, and support it and recommend it, we can get appropriations to deepen the waters outside. But in the harbors, we run against this proposition: there are so many private interests to be consulted, and property that would have to be condemned, and all that sort of thing, a hundred and one difficulties, more than I could enumerate, that you have to contend with, that the getting of your harbors deepened, is a very, very much slower process than it is outside. So that it would take years, for instance, to accomplish the depth of harbor you would want for a 25-foot channel. That is the reason I make the statement. What you could accomplish in a comparatively short time outside is a very difficult proposition in the harbors. And that is one proposition that really is confronting navigation today, that there are many harbors or quite a number of harbors that should, even under present conditions, be deepened materially, and passages for large boats made.

Q. Would you consider, Mr. Livingstone, that an increase

in the current along the river front at Detroit would be any detriment to navigation?

A. Yes, sir, it would be some, depending on how much or how little it was.

Q. Depending on the amount of the increase?

A. Yes, sir. Where you have a current, there are always more elements of danger than where there is no current.

Q. If Lake Michigan were lowered two feet, would navigation be affected anywhere except where the water is less than 30 feet deep?

A. I think it would, sir. I would have to look the chart over; I would not want to make the statement off-hand.

Q. Where?

A. I think it would make a good deal of difference, and yet if you ask me to enumerate where, I could not at the present moment. For instance I will explain this way: They have adopted, which is by all odds the best way in the world, the Lake Survey have adopted a method of sweeping the lakes for obstructions; and the result is that since they have adopted this method and put it in force, they are continually finding obstructions that we did not know existed before. Then in addition to that, you have got to bear in mind, you take a boat in a heavy sea, heavy storm, for instance one of our big boats, let us suppose that boat draws 22 feet of water, whatever she would draw; you see she has got to have under her in a heavy storm quite a few feet of water more than that to keep her from striking the bottom.

Q. How many feet?

A. Well, it would depend on the velocity of the wind, extent of the waves, etc., how much it was tossed.

Q. Assume a violent storm?

A. A violent storm would take six feet.

Q. That would be 28 feet?

A. Yes, sir.

Q. That would make 28 feet of depth necessary, so that if the water was more than 30 feet in depth, and if it lowered two feet, you would still be within the range then?

A. Yes, but here is what you would find, based on the experience of the Lake Survey: We have found since they have adopted what I regard as the perfect way of obtaining the depths of the lake, this sweeping we have found sporadic—it is not confined in any scientific way, but in a sporadic way we find hummocks, obstructions that I think two feet would make a wonderful difference in, in many cases. In

other words we would have a great many accidents if you lowered the lake two feet that we do not have now. Every foot you lower the lake you bring obstructions in force that do not exist before. That stands to reason.

Q. At the point where those obstructions were, getting outside the limits of my question, the water would not be 30 feet deep?

A. You may take for instance the water of a lake, the average depth of it might be 30 feet, and yet there might be a number of places in that lake where there might be hummocks or rocks sticking up like that, perhaps not as abrupt as that, but we find a good many.

Q. Would navigation be interfered with except at those points where the water was not 30 feet deep?

A. Why, certainly not, why would it? I do not see how it could be. But where it was affected it would be affected bad.

Q. Certainly, but I was speaking of the point where the water was fully 30 feet deep.

A. Well, you talk about, if I understand you, if Lake Michigan was lowered 2 feet, wasn't that your question?

Q. I asked whether or not if Lake Michigan was lowered two feet navigation would be affected except in those points where the water was less than 30 feet in depth?

A. Yes, but if you lowered Lake Michigan 2 feet, it would carry the Sault River two feet, and see what a serious proposition that would be.

Q. That would make it there less than 30 feet?

A. There are lots of places we haven't got 30 feet now.

Q. I am assuming a condition where we admit that where the depth of water is less than 30 feet a lowering of two feet would be a serious interference?

A. Oh, yes.

Q. But would it be any interference anywhere else, except where the depth was less than 30 feet?

A. How would it be possible to lower Lake Michigan two feet without lowering all the harbors two feet?

Q. I concede in those harbors it would interfere, but I ask whether it would interfere anywhere except at those points where the depth of water was less than 30 feet?

A. Perhaps not. I should be afraid that like dynamite that two feet would be loaded. When we used to have on the Lime Kiln only 12 feet, we sailed over places on the lakes

that we can't get near now. Every foot makes a great difference.

Q. You just spoke of the period of time when there was only 12 feet of water on the Lime Kiln Crossing?

A. Yes, 1867, '8 and '9; yes 12 feet.

Q. For what distance was that condition prevalent?

A. At the Lime Kilns?

Q. Yes.

A. It ran down three or four, four or five miles all through the rock cut.

Q. Do you recognize any difference in the cost of fuel required to move a loaded vessel from Lake Erie to Lake Huron as compared with that required to propel the vessel from Lake Huron to Lake Erie?

A. I don't think I clearly understand that.

Q. Does it cost any more for fuel to run a vessel from Lake Erie against the current into Lake Huron than it does to run the vessel from Lake Huron back into Lake Erie?

A. You are figuring as to whether there would not be a margin in favor of the current, you mean?

Q. No. I am figuring whether or not there is a margin against the current; if it costs more to run against the current than it does to run with it?

A. Yes; I would not undertake to figure it out.

Q. What I am trying to get at is in making your estimates of costs of operating a vessel, would you figure more fuel in making the up stream trip than you would in making the down stream trip?

A. If you went loaded, yes.

Q. Loaded both ways?

A. That is assuming the draft of water was the same both ways. Yes, a little more.

Q. About how much?

A. I can't give you that; I would have to make some figures on that. The man sitting back of you ought to be able to give you that.

Q. He is not testifying and you are. I wish to get it in the record.

A. I am willing to go on record for anything I know something about, but I want you to understand the older I get, the more I find out, the less I know. But it stands to reason, let me put it this way: Supposing two boats started from Duluth, boats of exactly the same size drawing exactly the same water; one was coming down and the other going up. If both

boats make the same rate of speed, you can naturally see you would burn a little more fuel. I can't tell you just how much, but you would burn more on the boat going up against the current than you would in the other, because the resistance, displacement, everything else would be greater. But when you come to figure it out I could not give you that offhand. You understand that is based on the supposition she would make the same time. But if she went a little slower and made fewer turns, take more time, she would accomplish the same result with the same amount of fuel.

Q. How much more time would it take?

A. I would have to figure that out, because I would have to take the number of revolutions. For instance if you turned exactly the same number of revolutions, the fuel would be the same. Every turn, every revolution per minute you increase the engine, why you can readily see it would cost more fuel, a little more fuel.

Q. Suppose that the currents in the Detroit and the St. Clair Rivers were reduced say 20 per cent?

A. Yes.

Q. From what you have said, I infer you would say that would be a benefit to navigation, if you had the same depth of water?

A. Well, there is a problem comes in there that I can't answer in this way: If you take the current out entirely, it is a question in my mind if that would not reduce the level of Lake Erie, and if you reduce the level of Lake Erie then you reduce the harbors in Lake Erie.

Q. Assuming the levels of Lake Erie and Lake Huron are not changed in any respect, and the depth of water is not made any different?

A. It seems to me the level of Lake Erie is 8 inches less than Lake Michigan.

Q. Assuming there is no effect whatever on the level of any of the lakes or the depth of water through which you are navigating, or any of the channels, would the reduction of 20 per cent in the current alone be a benefit to navigation?

A. It would be a benefit to this extent, although there are experienced vessel men who might differ with me on that subject: it would be a benefit to the extent of lessening the chances of collision; that and that only. There are some men that would rather have the current and make the extra time and take the chances of collision, so there would be a difference of opinion there.

Q. Suppose under the same conditions that the currents were increased 20 per cent, would you say that was a detriment?

A. Yes, sir, I should say it was a detriment, because that would increase the elements of danger.

Q. Would you consider that it increased the expense of operation substantially in any way?

A. The expense of operation?

Q. Yes.

A. Oh, practically not. If you eliminated the question of danger of collisions, no, not particularly. A boat going up stream would take a little more fuel. A boat coming down stream would be propelled somewhat faster so the thing would about even itself up.

Q. What do you consider the season of navigation?

A. Two hundred and forty days; 235 to 240. It varies a little some years.

Q. From what time to what time?

A. From its opening, we will say, along in the latter part of April and boats usually, many of them the insurance expires on the 5th of December at noon and if a boat leaves ten minutes before noon on the 5th of December, the Insurance Company has to carry her insurance in on that trip, on the pro rata basis as to her insurance.

Q. That is the date on which the insurance rates change, the 5th of December?

A. They expire, yes, sir. There was a time here, under certain conditions policies would run to the 10th, but now the policies are made to expire on the 5th. But if you are out, you understand, supposing you are on your voyage, of course by notifying the Company and paying the pro rata, they have got to see you home, but you can't start away, unless you get a special risk.

Q. If you get a special risk, the rate is much higher?

A. Oh, yes; very much higher.

Q. And that special rate is in force from December 5th on until the opening of navigation in April?

A. Yes. You would have to pay a very much higher rate, you know; some companies might not insure you at all.

Recess to 2 p. m.

Parties met at 2 o'clock p. m.

WILLIAM LIVINGSTONE resumed the stand for further cross-examination by Mr. Williams and testified as follows:

Q. What, if anything, has the Lake Carriers Association to do with the improvements of the harbors and connecting waters of the Great Lakes?

A. What have they to do with it?

Q. Yes.

A. Only this: that, for instance, if they think there is a harbor that needs improvement, and the necessities of navigation are such that it is important for them to get the improvement, they go first to the United States engineers of the district, who have that particular district in charge, and give them their reasons, give the engineer in charge their reasons why a certain thing should be done, and urge its being done, and then they go to Washington, if Congress is in session; go before the Rivers and Harbors Committee, if it is a subject that comes before them, and they have a hearing before the Rivers and Harbors Committee, give them the reasons why and wherefore, that this is a needed improvement, and that it should be done.

Q. It is a persuasive influence only?

A. Oh, entirely, Mr. Williams. Of course, if the Rivers and Harbors Committee, or whatever the committee is—depends on what it is; it may be the Light House Board; it might be something in the War Department; depends on each particular department the thing you want comes under.

Q. What I wanted to get at was this :does the Lake Carriers Association, or any member of it, contribute either directly or indirectly in any way to these improvements, from a financial point of view?

A. No, sir. I will have to qualify that perhaps on reflection in this way: that we have lights which are kept and paid for by the Lake Carriers Association.

Q. You have what?

A. Lights, aids to navigation of that kind, and if there was a wreck, for instance, in the way of navigation, there is always a good deal of delay; there is always a good deal of red tape about everything pertaining to the government, and if it is in the way we promptly light it and see that it is

lighted. We have a lot of aids to navigation that we pay for exclusively.

Q. My inquiry went only to the question of deepening and improving the channels.

A. That we go to Congress for, and when we want light houses and so forth, we go to the Lighthouse Department, and the Rivers and Harbors.

Re-direct Examination by Mr. Wilkerson.

Q. In your cross-examination this morning, Mr. Livingstone, you spoke with reference to currents in rivers, and the relation of the current to navigation. What do you know about the Chicago River, for instance, now, as to the effect of the reversal of the flow there, and the current in that river on navigation?

A. I know that the current there, in that narrow river, adds very largely to the dangers of navigation there.

Q. From practical experience, you know that?

A. Yes, sir. I know that the number of bridge accidents in Chicago—

Q. Attributable to the current?

A. Yes. They are very much larger than any other harbor I know of; I should say approximately double any other harbor. The accidents are greater in number than any other port on the lakes.

Q. Has there been any change in that since the flow of the river was reversed?

A. Well, I can't talk very intelligently about that; that is from personal knowledge. The understanding was, you know, that when the lake water was turned in there, if I understood it correctly, they were to have practically slack water there, but that is not the case. I have an impression that sometimes they have a current there of about three miles an hour, but I am not sure about it. I will say this by way of conclusion, and I am sure I am right, although I am not so sure about the others; I know the number of bridge accidents, etc., in Chicago is greater than any other port on the lakes, very much greater.

Q. With reference to the relation of the current to navigation, you spoke of two channels. I wish you would explain that a little more fully.

A. The reason I spoke of two channels was because it is like a double track on a railroad. With double channels, for

instance, a boat bound up would take one channel and boats bound down would take another, and therefore there is no meeting of boats. The great danger from collisions, you know, of boats coming together, is two boats meeting in the same channel; where the up bound boat, for instance, takes the easterly side and the down bound boat takes the westerly side, it is just like a double track on a railroad; all the trains going one way on one track and coming on the other; the danger of collision is very much minimized.

Re-cross Examination by Mr. Williams.

Q. Speaking of the number of accidents in the Chicago harbor, bridge accidents, is it not a fact that there are more bridges across the Chicago River than across any of the other rivers that you know of?

A. Well, I guess there are more. There are quite a few in Cleveland. I think there are more in the Chicago harbor. I would have to look that up before I could answer intelligently.

Mr. Williams: That is all.

Mr. Wilkerson: That is all.

FRANCIS S. SHENEHON resumed the stand and testified further as follows:

Re-direct Examination by Mr. Wilkerson.

Q. I would direct your attention, Mr. Shenehon, to two or three matters about which you testified on your direct examination: first, with reference to the effect of government improvements in harbors and channels, and the compensation which has been attempted in connection with those improvements. Is there anything which you care to add to what you have already said?

A. Yes, I would like to read an extract from my report on the preservation of Niagara Falls, an unpublished report.

Q. That contains some statements which you say are true?

A. Yes.

Q. Will you read it?

A. This is from Chapter 4, The Outflow of Lake Erie, page 21; an unpublished report. I say: "Artificial changes in the river (speaking of the Niagara River) regimen have

doubtless occurred, and these in part have restricted the flow, and have tended to raise the level of Lake Erie; and in part have made the flow more facile and tended to lower Lake Erie. The building of the International Bridge at Buffalo, whose piers and the rock banks flanking them reduced the cross section of the river at the crossing 18 per cent. doubtless raised Lake Erie. The building of the water works intake pier further up doubtless had a small conserving effect. The encroachments on the river channel for docks along the water fronts of cities like Tonawanda have a slight tendency to raise Lake Erie, and the dumping of material from dredged cuts has a very slight tendency in the same direction. On the other hand, the dredging out of river shoals facilitates the outflow and tends to lower Lake Erie, and the diversion of water above the first cascades for power purposes, by increasing the river flow, tends to lower Lake Erie. In the case, however, of a company throwing a wing dam into the river to deflect water into its intake, and diverting no more water than in a state of nature flowed in the intercepted portion of the channel, no lowering effect on the river or lake may occur. Indeed, in such a case if the water used and that wasted were less than the natural flow over the appropriated river bed, the effect might be to raise the river and Lake Erie. Any change in the river regimen between Buffalo and the rapids above the cataract coming from scour or deposition is believed to be exceedingly small, and the effect on the outflow of Lake Erie in a decade is inappreciable. Scour would serve to facilitate the flow and lower Lake Erie; deposition would serve to increase the resistance and raise Lake Erie. Such small changes as are likely to occur balance each other and the effect on the lake levels is mostly compensated."

Q. Is that all you care to add from that report?

A. Yes.

Q. Is there anything further you would like to add?

A. Yes. In regard to the Detroit River, I would like to make a statement that I have recently seen a chart which indicates that the shore line along the river front at Detroit has been reduced 350 feet by the dock improvements; and how much the decrease in river width has come from improvements on the other side of the river, I am not aware of.

Q. What would be the effect of that filling in?

A. That would be to compensate any increased outflow due to river improvements.

Now, in my prior examination, I stated that it was my

opinion that any lowering of the lakes that might have come from channel improvements was small; and since that time I have made some examinations of water levels, and I would like to introduce them.

Q. There were some questions put to you with reference to the change in the level of the lakes, computed as between two different periods arbitrarily selected. Now, have you made investigation of that, and eliminated on the one side the period of extreme high water, which tended to inflate the figures for that period, and eliminated from the other period the period of extreme low water which tended to change the average for that period? I mean have you made that computation, taking the average years, and eliminating what might be called abnormal or eccentric years?

A. I explained in my prior testimony that a comparison of the water levels for Lakes Michigan and Huron, say from 1860 down to 1890, and a later period from 1890 on to 1908, would not be a fair comparison of any permanent lowering that might have taken place in the lakes, for the reason that in the former period the record high water since 1860, which is that about 1886, comes in, and in the latter period the record low water for all time that we have any record of comes in.

Q. That was for 1905, was it?

A. Yes. The counsel for the Sanitary District, Mr. Williams, suggested that I leave those out, and I have made that computation and will give the results. I have divided the period from 1860 down to 1908, so as to include in the prior period the twenty years from 1860 to 1879, inclusive. In the second period, I have taken the years 1880, 1881, 1882. Then I have cut out five years of high water, 1883 to 1887, inclusive. I have included the years 1888 to 1894, inclusive; then cut out the four years of low water, 1895 to 1898, inclusive, and included the years 1899 to 1908, inclusive. That gives twenty years in the latter period, plus any comparison with the twenty years from 1880 down, and the results of the computation indicate for Michigan and Huron (and this is by the Milwaukee gage) an elevation of 581.71 for the earlier period and 580.90 for the latter period, which shows the elevation of the lake in the latter period .81 lower than in the earlier period. For Lake Erie, the same years indicate 572.86 for the earlier period; 572.36 for the latter period, with a lower lake level of 0.50 for the latter twenty years as compared with the prior twenty years. For Lake Ontario, the

elevation for the prior period is 246.51 and for the latter period 245.98; showing a lower water by 0.53 feet for the latter period as compared with the prior period.

Lake Superior for the same periods shows for the earlier period 602.35 and for the latter period 602.33 or practically the same elevation for the two periods.

Q. I will ask you to enumerate those years in which you say the second period ran?

A. The 29 years from 1880 to 1908, inclusive. From those years I have excluded 1883 to 1887, inclusive, five years; and 1895 to 1898, inclusive, four years more, making an exclusion of nine years. In these exclusions I have cut out the mountain peak of 1886, and cut out the valley of 1895, and I think the resulting comparison is a fair one.

Q. Along back in that period from 1883 to 1887, there was what was generally known as a period of high water, wasn't there, all over the country?

A. Oh, yes. I am not certain about its being all over the country. I think I have mentioned the fact that the period of 1895 was a period of low water all over the country. I am not certain as to how it was in 1886.

I would like to make a little further statement regarding this matter of lake levels, and make another comparison. I stated in my prior testimony that a certain relation seemed to hold between Lakes Michigan and Huron and Lake Erie. That is when Lake Michigan and Huron went up one foot, Lake Erie went up .7 of a foot, that is comparing a number of years together. But I have selected a method of comparing the relative elevations of the lakes, which does not require us to use that 70 per cent. relation. I have selected the ten years from 1864, or between 1864 and 1880, and a second ten years between 1888 and 1908, in which the elevation of Lake Erie is practically the same for each of the two periods. For the earlier period, 1864, '5, '6, '7, '8, '9, 1872, 1873, 1879 and 1880. For the latter period 1888, 1889, 1890, 1893, 1894, 1904, 1905, 1906, 1907, 1908. Now the elevation of Lake Erie for the earlier ten years is 572.48, and for the latter period it is 572.46. Now, I have added .02 to the latter period, making it 572.48, the same as the earlier period. And I have added to the latter period for Lake Michigan .03 and for Ontario .02 and for Superior .02. That gives us a very fair comparison. Now, for Michigan and Huron, for the earlier period, I have an elevation of 581.18 and for the latter period 581.06. Remembering that I have added .03 to that latter period, this shows that

for the same level of Erie, Lakes Michigan and Huron are lower by 1½ inches in the period after 1886 as compared with the latter period. For Ontario, the earlier period shows 246.16 and the latter period 246.37, indicating that Ontario is .21 foot higher for the latter period. And for Lake Superior, the earlier period shows 602.15 and the latter period 602.39, showing Lake Superior 0.24 higher for the latter period than for the prior period. This would indicate that Lakes Michigan and Huron had lowered about an inch and a half with respect to Lake Erie. That Lake Ontario should be higher in the latter period is what we expect, because the building of the Gut dam in 1903 raised the elevation, as I have previously testified, about five inches. That Lake Superior also should show higher is proper, because the building of International Bridge, the bridge piers, come in in the second period, while it was not present in the first period.

I want to state with all possible frankness and clearness that the fact of channel improvements by giving a more concentrated section for the flow of the water does have a tendency to facilitate the river flow. And I wish to state with equal clearness the compensating effects which I have spoken of, the deposition of the dredged material, the encroachments on the shore along cities, the building of docks. And the testimony of the water levels themselves indicates that the compensation is very nearly complete; not entirely complete, I should say. But the case of St. Mary's River, where I testified that the pool below the locks had been lowered one foot, I believe is not reproduced in any such measure in any of the lakes, or in the Lakes Michigan, Huron and Lake Erie. We know as a matter of fact Lake Ontario has come up, and we also know Lake Superior has come up in the period since 1888 as compared with the earlier period.

Q. Suppose the compensating effect is not complete and that by reason of the improvements in the channels, government improvement in the channels, there has been some lowering. What would you say as to the comparative effect under that condition of the diversion of this additional quantity of water at Chicago?

A. I should say that if the lakes were lowering by reason of channel improvements or scour, or from any cause, and I should have mentioned earlier the possibility of deforestation entering into the problem.

Q. What do you mean by that?

A. I mean that as the shores are cleared of the timber

and the lands are plowed that the evaporation on the land may be greater than it was in the earlier days. That whole question is one that is in dispute, and I do not care to pass on what the effect may be. I mention it simply as a possible element in the case.

Q. Well, now, proceed, on the assumption that as a result of these natural causes and artificial improvements on the part of the government there has been this lowering tendency, what would you say as to the comparative effect of the diversion at Chicago?

A. I should say that if Lakes Michigan, Huron or Erie had been lowered by these improvements for purposes of navigation, and by reason of natural causes, that any further lowering by the diversion at Chicago would be all the more serious.

Q. I direct your attention to your testimony as to the backwater effect of Lake St. Clair. Is there anything that you wish to add to what you said on that subject?

A. I wish to state that the percentage of retardation of the flow that I have stated to be two-thirds of 1 per cent. for each one-tenth change in the elevation of Lake St. Clair is a very approximate quantity, and should not be applied through any large range. It was intended to apply to a few tenths on either side of the mean condition.

Q. Is there anything further, Mr. Shenehon, that you wish to add to your testimony on these different matters?

A. There is nothing that I now think of.

Re-cross Examination by Mr. Williams.

Q. You referred in your testimony, Mr. Shenehon, to the effect of the improvement of the St. Mary's River. Is it not a fact that it was found impossible to compensate for the increased carrying capacity of the channels there, without introducing such currents as would make navigation through the improved channels very dangerous?

A. I do not know as a matter of fact the elements governing the design of the regulating works or the compensating works. I simply know that as a matter of fact the level of the water has been allowed to drop down.

Q. Do you not know as a fact that the reason it was allowed to drop down was because compensation could not be made without introducing such a current—

A. I do not know; I have never heard any explanation. I testified that at the middle Neebish a dyke was thrown through the shallow water, and I think the compensation was impossible in the middle Neebish.

Q. In your opinion, if compensation had been attempted here would it have introduced into the channel a current that would have been considerable?

A. I think the method pursued, or what has come out of it, was the proper engineering design or engineering decision.

Q. But if the attempt had been made there to compensate, in your opinion would there have been a considerable current?

A. Oh, yes; the conditions there were extreme. In the case of the middle rapids cut, they cut through almost dry land; in the case of the west Neebish, as I testified, rocks are showing above water, two or three feet of water, and they cut down to twenty odd feet of water. And the middle Neebish, I don't know the original condition there, but I imagine it is not very deep; it was less than 12 feet of water, because the old vessel track through the east Neebish had about 12 feet of water in the old days.

Q. In tabulating these elevation, dividing them into periods, why did you make the division of periods at 1880, in making your comparisons?

A. I took the first twenty years and compared it with the second group of twenty years, excluding two groups, one of five years in the 1886 period and the other of four years in the 1895 period. Taking five years out of the latter period, and only four out of the prior period would have made very little difference in the comparison.

Q. As a matter of fact the differences in elevation between Lake Huron and Lake Erie were greater during the first three years of the second period, that is 1880, 1881 and 1882, than they were for any other year after 1890, except 1901, weren't they? The difference in elevation for 1880 was 8.82, was it not?

A. 8.72, I have it.

Q. You have the whole year. I was taking the season of navigation. 8.72 is correct for the whole year. 1881 is 9.14. Suppose a comparison were made of those two periods, a period of 30 years from 1860 to 1889, omitting the years 1883 to 1887, inclusive, and taking for the second period 1890 to 1908 and excluding the years 1895 to 1898, inclusive?

A. Your exclusions in the earlier period are what?

Q. From 1883 to 1877, the same exclusions that you made except we divide at 1890, the time when these improvements were made.

Mr. Wilkerson: That is you take a 25-year period as against a 14-year period.

Mr. Williams: Practically.

Mr. Wilkerson: You have that computation, have you, Mr. Shenehon?

A. Yes. Professor Williams and myself have made the computation for two periods, the earlier period being for 25 years, that is, from 1860 to 1889, inclusive, with the exception of the years 1883 to 1887, inclusive. That is it is a 30-years period, excluding five years. The second period is from 1890 to 1908, inclusive, with the exception of 1895 to 1898, inclusive; that is four years excluded. The earlier 25-year period shows for Lakes Michigan and Huron an elevation of 581.69; the latter period 580.67. The lakes were lower in the latter period of 15 years by 1.02 feet than in the earlier period of 25 years. For the same periods for Lake Erie, we have the earlier period 572.84 feet and for the latter period 572.23, showing Lake Erie 0.61 feet lower for the latter period of 15 years than for the earlier period of 25 years. For our relation of 70 per cent. in Lake Erie to one foot in Michigan and Huron, we would expect Lake Erie to be .71 feet lower in the latter period than it was in the earlier period. This computation we have just made shows it was 0.61 lower, which is corroborative of the statement I made earlier that Lakes Michigan and Huron appear to have lowered about 1½ inches as compared with Lake Erie. This makes it 1¼ inches. As regards the actual lake levels, the comparison of these two periods is an unbalanced one, 25 years in the former and 15 in the latter, and should be considered with reference to that selection of years.

Mr. Wilkerson: There is nothing further, Mr. Shenehon, that suggests itself to you?

A. No.

Adjourned sine die.

Cleveland, Ohio, July 8, 1909.
11 o'clock a. m.

Parties met pursuant to notice.

Present: Mr. Wilkerson and Mr. Williams.

HARRY COULBY, a witness called on behalf of the government, was first duly sworn and testified as follows:

Direct Examination by Mr. Wilkerson.

Q. What is your full name?
A. Harry Coulby.
Q. Where do you live?
A. Cleveland.
Q. What is your business?
A. President of the Pittsburg Steamship Company, lake transportation.
Q. How long have you been engaged in lines of business connected with lake transportation?
A. Since 1886.
Q. And in what different capacities?
A. Manager of steamships, docks and everything connected with lake transportation.
Q. What, in a general way, is the nature of the commerce which is carried on in the vessels of your company?
A. They carry iron ore, coal, sometimes grain.
Q. And between what points, principally, is that commerce conducted?
A. Two Harbors, Duluth, Superior, Ashland, Marquette, Escanaba and the Lake Michigan ports, Milwaukee, South Chicago, Chicago, Gary, and to all lower lake ports.
Q. And then on east, Detroit?
A. Yes, and these lower lake ports here.
Q. Cleveland?
A. Cleveland.
Q. Buffalo?
A. Buffalo, Erie, Conneaut, Ashtabula, Fairport, Lorraine, Huron, Sandusky, Toledo.
Q. What percentage of commerce of your company goes as far as Lake Superior, or comes from Lake Superior?
A. About 80 per cent. of it.
Q. Approximately how many vessels are operated by your company?

A. We own 106 vessels, and we generally charter about 100 more, in a normal season. We have about 200 ships in our employ.

Q. Now, with reference to those of your vessels in which commerce is conducted to and from points on Lake Superior, what is it that determines the size of the load that one of those vessels can carry?

A. It is the locks at the Sault.

Q. That is for vessels that are capable——

A. For the large model ships.

Q. Those that are capable of loading to a greater depth?

A. Yes.

Q. How many vessels has your company that are capable of loading to 20 feet, or more?

A. Sixty-one.

Q. Are you able to state approximately the number of tons carried on those vessels in a season?

A. About 12,500,000 tons.

Q. That is on the 61 vessels capable of loading to 20 feet, or more?

A. Yes.

Q. That is just on those 61 vessels?

A. That is on the 61 ships, we carry 12,500,000 in a season.

Q. As to the vessels that go to Lake Superior, you say the depth to which the vessels may load is determined by the water in the locks?

A. In the locks, yes.

Q. The Poe Lock?

A. Yes.

Q. How deep may the vessels that are going to Lake Superior be loaded now, do you know?

A. Nineteen feet, three, through the Poe Lock.

Mr. Williams: Three-tenths feet, or three inches?

A. Three inches.

Mr. Wilkerson: As to the vessels that are not going to Lake Superior, what determines the size of the load which they carry?

A. Ballards Reef, and the shallow waters across Lake St. Clair.

Q. And do you know to what depth those vessels may now be loaded?

A. They are loading to about 20 feet now.

Q. Are you able to state the number of tons for the average vessels, I mean the large vessels about which you have

testified, of your company, which will increase its draft one inch when loaded to a depth of about 19 or 20 feet?

A. About 100 tons to the inch.

Q. Assume that there should be a diminution in the depth of the water at these points with reference to which you have testified at the locks at the Sault and at Ballards Reef, assume a diminution of an inch, what would be the effect of that upon the quantity of freight which could be carried in these large boats?

A. It would reduce them about 100 tons per inch or 100 tons per trip.

Q. That would be for each ship?

A. Yes.

Q. Each ship per trip?

A. Yes, each voyage.

Mr. Williams: Do you go loaded both ways?

A. The round trip, for each cargo.

Mr. Wilkerson: About how many trips do one of those large vessels make in a season?

A. We average about 25 trips in a season.

Q. That is 25 round trips?

A. Yes, sir.

Q. With reference to the operating expenses, including fuel and dock and loading charges, how do those compare when a vessel draws, say 19 feet, as compared with the same vessel drawing 19 feet 6 inches?

A. There is no difference per trip in the operating charges but there would be a difference per ton, because of the reduced number of tons carried.

Q. How about the amount of fuel it would take?

A. Oh, it would not make any appreciable difference.

Q. And what do you say as to a vessel loaded 19 feet 6 inches, as compared with one loaded 30 feet?

A. It would be so slight you would almost lose sight of it. There would be no appreciable saving there.

Q. Are these 61 vessels, about which you have testified as being operated by your company, all of substantially the same size, or do they vary?

A. No, they run from 7,000 tons up to about 11,000.

Q. Can you give us approximately the dimensions of the largest of those vessels? Which is the largest?

A. The Cole is the largest, she is 605 feet long.

Q. What is the draft?

A. Fifty-eight feet beam and 32 feet deep.

Q. And if you had enough water at these critical points of navigation, how deep could you load that vessel?

A. Oh, that would be perfectly safe to 25 feet.

Q. How many vessels of approximately that size are there in the fleet of your company?

A. Of which size?

Q. The size of the one you have last testified about?

A. We have got 12; we are building two more. We will have 14 of the large size; but all of them have about the same depth; they are all of them from 30 to 32 feet deep, so that every one of those 61 ships could load to 25 feet.

Q. They could be loaded to 25 feet?

A. Yes.

Q. If you had the water?

A. If you had the water.

Q. As to all those vessels, what is the effect of a permanent lowering of the water in the lakes, one, two or three inches?

A. Every time you lower it an inch, you reduce the carrying capacity that much; reduce the earnings that much, without reducing the operating cost; in fact increase the operating cost on the per ton of freight carried, because you have a lesser number of tons per trip, over which to divide your operating cost.

Q. Are you able to give in a general way what the added expense is, or rather the added cost of transportation, due to diminishing the depth to which the vessel can be loaded, two or three inches?

A. I have not prepared any statistics on that.

Q. That could be easily determined from the figures you have given, could it?

A. Yes.

Q. How would you do that? About what is the cost per ton? If you have anything that will give us the basis for forming some idea as to what the effect of this lowering is upon the cost of transportation, I wish you would give it to us.

A. The cost of carrying the ore on about 19 feet 6 is 50 cents a ton.

Q. That is between what points?

A. That is from Lake Superior points to lower lake ports.

Q. You say that is to a depth of 19 feet 6?

A. Yes.

Q. About how many tons will one of these large vessels carry, loaded to that depth?

A. About 10,000 tons.

Q. Do you know anything with reference to the depth of the water in any of the harbors into which your boats go, as to whether or not the size of the load which can be carried is limited by the depth of the water in those harbors?

A. All the harbors have been dredged out to take care of the ships that could come over what I call the "necks of the bottle," that is the Poe Lock and Ballards Reef.

Q. Are there any which have been dredged only up to the point of taking care of the vessels which come over these points?

A. I do not think any of the harbors have been dredged beyond that point.

Q. So that as to practically all the harbors into which your vessels go, the lowering of the water in the lake would affect them?

A. It would be very disastrous to the harbors.

Q. That is to say it would affect them how?

A. It would affect the dock lines and the docks all around the harbors; I think the foundations of the docks.

Q. And with reference to the size of the load a vessel would carry into the harbor, would it have any effect on that?

A. It certainly would.

Q. The same effect as it would have with reference to going through the locks at the Sault?

A. Just the same.

Q. And through the river at Detroit?

A. Just the same.

Q. Have you any particular harbor in mind which would be affected that way?

A. Oh, I think every harbor along the south shore of Lake Erie would be affected.

Q. Are you able to state in a general way what would be the total effect upon the vessels which are operated by your company on the basis of the business for a season if there was a permanent lowering of say three inches, or six inches?

A. You mean per inch, on our 61 ships?

Q. Yes.

A. It would reduce the carrying capacity of the fleet 610 tons per trip; on 25 trips would be 15,000 tons.

Q. Is it 610 tons?

A. No, 6,100 tons.

Q. Sixty-one hundred tons?

A. Yes. That would be 152,000 tons a season.

Cross-Examination by Mr. Williams.

Q. The total tonnage of the 61 vessels that you have mentioned as having a draft of more than 20 feet, I understood you to say was about 12,500,000 a season?

A. Twelve and a half million tons.

Q. Per season?

A. Yes.

Q. And that is on the basis of not carrying to exceed 19 3 through the Poe Lock, and about 20 feet through the St. Clair River, Lake St. Clair and Ballards Reef?

A. That would be 19 feet 3; that is based on 19 feet 3, coming down, because it is the lowest draft that governs.

Mr. Wilkerson: That is 19 feet 3 for all the vessels that go to or come from Superior?

A. Yes. We do not trade many of these boats to Lake Michigan; that is from Lake Superior to Lake Erie.

Mr. Williams: All the vessels then that carry cargoes to the Lake Erie ports come from Lake Superior?

A. Not all of them.

Q. Are there any considerable number of the 61 vessels, concerning which you have testified, that get their cargoes this side of Lake Superior, and deliver——

A. Very few of those ships; occasionally we load some of them from Lake Superior to South Chicago or to Gary, and then run them down to Escanaba, and load them from Escanaba to Lake Erie; but as there is only about 20 per cent. of our business that comes from Michigan to Lake Erie, 80 per cent. of it comes through the Sault canal.

Q. So long as the draft of the vessels is limited at the Poe Locks to 19 feet 3 inches, any lowering of the Great Lakes, or any harbor or connecting water, which does not bring it below the 19 feet 3, would not have any effect on the greater portion of the navigation carried on by your company, assuming that there was still 19 feet 3?

A. Of course if there is still 19 feet 3 of water, we would be just where we are today, if the water is not lowered.

Q. So that in order to have any lowering effect on the business of your company it would have to be a lowering to an extent that would bring the water below 19 feet 3, at the present time?

A. Not necessarily.

Q. So far as the cargoes that come through the Sault locks are concerned?

A. On the present draft of water in the lakes, which of course governs the draft of water through these connecting places; the draft of water in the lakes.

Q. The Pittsburg Steamship Company is a corporation?

A. Yes.

Q. Organized under the laws of what state?

A. I think it is West Virginia.

Q. And the stock of the company is held by whom?

A. The United States Steel corporation.

Q. Who are the principal customers of the Pittsburg Steamship Company; that is, for whom is this transportation of iron ore and coal carried on by you?

A. For the subsidiary companies of the corporation.

Q. In other words, the United States Steel Corporation does its own transportation?

A. No.

Q. Carries on its own transportation through its subsidiary companies?

A. The Pittsburg Steamship Company carries part of the ore, probably 50 per cent. of the ore that the United States Steel corporation and subsidiary companies use; and then the United States Steel corporation, as the Pittsburg Steamship Company, has to go outside and charter independent ships.

Q. But does the Pittsburg Steamship Company carry any ore for any one except for the United States Steel Corporation?

A. No.

Q. Or one of its subsidiary corporations?

A. No.

Q. What percentage of the vessels owned by your company having a draft of more than 20 feet, the 61 vessels that you testified to, are loaded in both directions, when they make their trips through the season?

A. Loaded both ways?

Q. Yes.

A. You mean of the whole fleet?

Q. Of the 61 vessels?

A. Of that 61 vessels, we would not have probably over 2 per cent. loaded both ways.

Q. And when they are loaded going the other way, what is the nature of the cargo?

A. Coal.

Q. Do they load to the same capacity and depth as they do coming this way?

A. Yes.

Q. And for whom is the coal carried?

A. For everybody.

Q. As a common carrier?

A. We carry coal, corporation coal, and we sometimes carry coal for outside parties.

Q. Would an inch difference in draft of a vessel make the same difference in the capacity to carry coal as it would iron ore; in other words would an additional inch mean the same amount of coal?

A. Just about the same.

Mr. Wilkerson: That is, the point being whether one is as heavy as the other?

A. There is about 240 pounds difference; coal goes 2,000 pounds to the ton; ore, 2,240.

Mr. Williams: That would not affect the inch?

A. It is the inch of draft; it is not the inch of load inside the ship. It is the inch it puts the ship down that you are after.

Q. It takes the same amount of weight to put it down one inch with the one as with the other?

A. Yes, doesn't make any difference if you fill it with feathers, if you have the cubic capacity to put the ship down.

Q. Of the vessels that are chartered by your company, you say, in an ordinary season, you charter perhaps 100 vessels in addition to those owned by your company?

A. Yes.

Q. What percentage of those would you say have a draft of 20 feet or more?

A. I would say 90 per cent. of those.

Q. Have a draft of more than 20 feet?

A. Yes.

Q. What is the total tonnage of vessels operated by your company, that are owned or chartered by it, having a draft of more than 20 feet, per season?

A. The total tonnage?

Q. Yes.

A. I should say 20,000,000 tons.

Q. What would you say was the total tonnage of all your vessels of every description, both owned and chartered, whether they have a draft of more or less than 20 tons?

A. Whether they have more or less? About 23,000,000 tons.

Q. In other words the vessels having a draft of less than 20 feet would carry about 3,000,000 tons per season?

A. Yes.

Q. What is the total tonnage on the Great Lakes in a season?

A. I think about 75,000,000 tons.

Q. So that your company practically handles about 33 per cent. of the total tonnage on the Great Lakes?

A. Yes, sir.

Q. What has been the tendency during the past, say 10 years, in the building of vessels, as to size, capacity, draft?

A. Well, all the boats that cannot load to 20 feet, we scrap them or sell them as quick as we can. All the ships we build or that anybody else builds, are built looking to and hoping for a 25-foot channel.

Q. Your answer to my question as to the tendency during the past ten years is that there is a tendency to increase the tonnage capacity of vessels being built?

A. That is it.

Q. To what extent, what percentage would you say?

A. The last 10 years?

Q. Yes?

A. Oh, about 100.

Q. Looking to a capacity of 25 feet, depth of water of 25 feet at the critical points. Can you explain, just as briefly as you may, the reason why vessels are built with a draft of 32 feet, when you do not anticipate any more than a 25-foot depth of water?

A. We have to have some freeboard on a ship, to make her seaworthy.

Q. Will you explain why it is advisable, or proper, as I assume it is, to build a vessel with a greater draft than you expect to have depth of water for?

A. We have not built any of them yet.

Q. You have some now with a draft of 32 feet?

A. They are 32 feet deep; they could not load to 32 feet.

Q. You could load to 25 feet?

A. You could load them to 25 feet.

Q. They would not be capable of being loaded to more than 25 feet in any event?

A. No, I don't think so. That of course would be an engineering proposition to work out, as to what freeboard a ship ought to have. We never have got anywhere near the danger line yet.

Q. Do you know the depths at the harbors at South Chicago and Gary and Chicago?

A. No, I don't know just what depth they have there. They have got plenty of water there for the——

Q. Is it considerably deeper than the water at Ballards Reef, for instance?

A. Yes, they have deeper water there.

Q. How are the harbors at Cleveland?

A. Oh, that just depends on where you go; 21, 22 feet up the old river, and dropping down to 19 feet at the upper end of the river.

Q. Are there any other elements that you take into consideration in loading a vessel besides the depth of the water? Of course that you take into consideration first, but what other conditions would you take into consideration in determining how deep a vessel can load?

A. On these large ships that we are now talking of?

Q. Yes.

A. No other conditions but the depth of water.

Q. Does the velocity of the current in a stream have any effect on the cost of operating, or the danger of operating, or the general business of navigating the Great Lakes or connecting waters?

A. The velocity of the water makes it more dangerous to operate, of course.

Q. What velocity would you consider a dangerous current?

A. Well, that is a pretty broad question to answer. It would depend entirely on the channel, the width of the channel.

Q. Are there any dangerous currents now in any of the connecting waters of the Great Lakes?

A. No, there is only one at Port Huron; that is not dangerous; about a six-mile current through there.

Q. You think a six-mile current is not a dangerous current?

A. It is not as safe as no current at all; still it is not what you may term a dangerous current for operating ships through there.

Q. Would you consider that a decrease in the velocity of the current at any of those points where the current is from four to six miles an hour would be of advantage to navigation in any way?

A. No, not a particle.

Q. Would an increase of current be any detriment?

A. It would if you increased it enough.

Q. Any increase above six miles an hour?

A. Any increase above six miles an hour? That is a pretty broad question. That might be 6 or 10 or 25 miles. There is a danger line; I do not know what it is and nobody else knows.

Q. Assume there is a current of six miles an hour. Isn't it a fact that any increase in the velocity of that current above six miles an hour would be a detriment to navigation in the proportion the increase bore to the present current; that is a very small increase would be a slight detriment and a large increase would be a very great detriment?

A. Yes, you put it that way, and let some one else decide on the question of the small increase and the large one.

Q. Would any increase at all be a slight detriment to navigation?

A. The more you increase the current, of course, the more dangerous it becomes.

Q. Are the insurance rates based in any way on the condition of the currents, the dangers incident to swift waters?

A. No.

Q. You do not think that the insurance rate would be increased on you if the currents would be increased?

A. They would be if it increased the accidents; they are based on the accidents, the insurance rates are.

Q. And accidents would be more likely to occur with a swift current than they would with a slight current?

A. The more swift the current, the more likely you are to have accidents.

Q. Have you ever known of any accidents occurring at the Limekiln Crossing as a result of the current there?

A. I have known of a good many accidents there, but I am not prepared to say they were on account of the currents altogether.

Q. Do the currents have some contributing influence, in your opinion?

A. Yes, the currents and the crooked channel together.

Q. Now, do you know the velocity of the current through the Limekiln Crossing?

A. No, I do not know what it is there; what the current is through the Limekiln.

Q. Mr. Wilkerson asked you to make a hurried computation as to the effect upon the tonnage carried by your company

of a decrease of depth of one inch and I believe you figured 61 vessels with 100 tons per inch for each vessel, making 6,100 tons?

A. Yes.

Q. Would you say that in all your 61 vessels an inch meant 100 tons?

A. No, that would be the average. Some would go higher than 100 tons; that would be about the average.

Q. What would be the difference in tonnage for each inch in the Cole, for instance, which is the largest vessel?

A. That would probably go 120 tons. Of course the higher you go, the more she carries; that is the deeper down you go the more she carries.

Q. What would you say of the Corey?

A. Well, it would be a fraction; it would be pretty hard to tell the difference there; it would be pretty close to the same, probably 110 or somewhere along there.

Q. And you think 100 tons per inch is a fair average for the 61 vessels?

A. Yes.

Q. Do you figure that for 25 cargoes?

A. Trips, yes.

Q. For the season?

A. Yes.

Q. Do you know what the average tonnage for these 61 vessels is, for the year?

A. The average?

Q. Yes.

A. About 8,200 tons to the cargo.

Q. What is the average capacity?

A. About 200,000.

Q. The average capacity of the 61 vessels?

A. The average capacity would be about 8,200 tons.

Q. That is the average tonnage that is actually carried, is it not?

A. That is the average capacity of the 61 ships.

Q. Have they been carrying to their full capacity?

A. That is based on 19 feet 3.

Mr. Wilkerson: Of course most of them could be loaded to 25 feet?

A. They could all be loaded to 25. That is the average capacity of those ships per cargo, based on 19 feet 3 inches.

Mr. Williams: What was the actual amount carried on those 61 vessels last year?

A. I haven't got that figured up.
Q. Do you know what number of trips were made?
A. They averaged 25 trips.
Q. Was that the average for last year or the average for several trips?
A. No, that was the average for year before last, when we had a full season; that is the average full season's capacity.
Q. What was it last year?
A. I don't remember. We had a short season. We didn't get started last year until some time in June.
Q. Can you give us an approximation as to the number of trips, average number of trips for the 61 vessels last year?
A. No, I could not do that without figuring it up. I am giving you the average season's capacity of the ships.
Q. That is based upon one season, namely, season before last?
A. Based upon a season where we operate the full season.
Q. Your figures are based upon your actual experience season before last?
A. Yes.
Q. That one season?
A. Yes.
Q. You say that would be a fair average for any season providing the conditions were the same as then?
A. For 10 seasons provided the seasons average the same number of days, and we operated the entire season.
Q. But they don't always do that?
A. Without there are labor troubles, or something unusual happens.
Q. How about last season?
A. Last season they did not, because of labor troubles on the lakes.
Q. And this season?
A. This season we have had labor troubles.
Q. So that by reason of some condition, whether labor troubles or other matters, that does not make it an average for the last three seasons, does it?
A. No.
Q. What is the average cost of one of these large vessels?
A. About \$400,000; \$400,000 to \$450,000.
Q. How many days do you consider an average season of navigation?
A. About 240.

Q. What is the operating expense of one of these large vessels, the average for the season?

A. About 50 cents a ton.

Q. Without reference to the tonnage, in dollars and cents?

A. Take the steamer Rogers, in 1907, she carried 323,000 tons of ore. Her operating expense was $127,000; about 40 cents a ton.

Q. What was the season that year, 240 days?

A. Yes. I will tell you how many days she was running, if you would like to have that.

Q. Yes.

A. She was actually operated 223 days.

Q. How many trips did she make?

A. Twenty-nine.

Q. Would you say that was a fair average of the operating expense of one of those large vessels, about $500 a day?

A. Yes, that is a fair average for operating expense.

Q. What is included in the operating expense?

A. Everything.

Q. Insurance?

A. Yes.

Q. Repairs?

A. Yes.

Q. Depreciation?

A. No.

Q. Just ordinary maintenance?

A. Just ordinary maintenance and operation.

Q. Coal?

A. Fuel, yes, everything that goes into operation but depreciation and interest.

Q. What would you consider a fair charge for depreciation and interest on a vessel of that kind?

A. Five per cent. a year.

Q. For both, or each?

A. For what?

Q. Depreciation?

A. Five per cent. a year.

Mr. Wilkerson: That is, you charge off 5 per cent. each year?

A. Yes.

Q. To get the value of the vessel?

A. That is what ought to be charged off.

Mr. Williams: What do you consider a fair charge for interest on your investment?

A. All that you can get.

Q. I mean you would charge off something for interest on your investment, before you figure any profit, wouldn't you?

A. Yes, you ought to charge off 5 per cent. a year.

Q. For interest?

A. Five per cent. a year for depreciation, and 5 per cent. a year for interest on steamship property is not enough.

Q. It is enough to start you out, and then anything above that would be profit?

A. Yes.

Q. You would not consider you were making a profit if you did not get more than 5 per cent. on your investment, would you?

A. No.

Q. So that 5 per cent. would be a fair charge for interest?

A. Yes.

Q. That is to say, the actual cost of transporting that 323,000 tons was about 40 cents a ton?

A. Yes.

Q. Does that include the unloading charge?

A. Yes, that includes the unloading charge.

Q. Does your company make a profit on that in addition? I do not want to try to get into the secrets of your business, but I mean is that what determines your earnings, what it actually costs, or do you charge the other subsidiary companies the same as you would a third party?

A. We charge the docks. We do not take it all to corporation docks. We take that ore to everybody's dock, that reaches the corporation; there is a regular dock charge for unloading.

Q. That is for unloading?

A. Yes.

Q. The charge for transportation, do you charge the actual cost, or do you charge something in addition to that?

A. We charge the actual cost of transportation, which includes the actual amount we have to pay to the dock companies for unloading it.

Q. Are the tons you speak of the vessels carrying gross tons?

A. Yes.

Q. Two thousand two hundred and forty pound tons?

A. Yes, ore goes by gross ton; coal by net.

Q. This was all iron ore that you are speaking about that the Rogers carried?

A. All iron ore that the Rogers carried; didn't carry coal at all.

Q. Do you carry your own insurance on your vessels?

A. Yes.

Q. And make a certain charge for it.

A. Yes.

Q. That is included of course in the actual cost of operation?

A. Yes.

Q. Does that include a profit to the company or is that the actual cost of carrying the insurance?

A. We charge our ships the insurance just exactly the same as it costs us to insure in old line companies, just the same rates.

Q. When was the William E. Corey built?

A. In 1906.

Q. Take the Corey for 1907, could you tell the number of days it ran, the number of trips it made and the actual operating expense?

A. The Corey was in commission 232 days. She made 29 trips. The operating expense was $123,404. You want the total tonnage now? She carried 295,802 tons; the cost was 41.7 cents per ton.

Q. What if anything has your company done, either individually or as a member of the Lake Carriers' Association towards improving the condition of navigation on the Great Lakes?

A. We do not do anything only as members of the Lake Carriers' Association.

Q. You are one of the directors of that association?

A. Yes, I am one of the directors.

Q. What have you done as an association?

A. We keep after the government, and keep trying to get them to spend money on this shallow water. The deeper the water the less per ton it costs to carry freight. The consumer pays the tax, you know.

Q. And you are working in the interest of the consumer?

A. This consumer right here. But on the broad proposition, the bigger load you can carry in a ship, the cheaper you can carry it; competition takes care of that.

Q. You are familiar with the iron ore trade I assume?

A. Yes, sir.

Q. Have you any opinion as to the length of time during which the supply of iron ore at Lake Superior will last?

A. I know just like everybody else knows that it will last until it is done; nobody knows when that will be.

Q. You haven't any opinion on the subject then?

A. Not a particle. It will last as long as I live, and I am not worrying much about the other fellow.

Q. What is the average length of time consumed in making a trip with one of these boats?

A. About nine days.

Q. For the round trip?

A. Nine days.

Q. About how long a time is consumed in loading and in unloading each, that is separately?

A. Oh, they probably load them in the average time of nine or ten hours; unload them in about the same length of time.

Q. Is there any difficulty in getting to the dock at times?

A. If the water is low.

Q. Any other difficulties?

A. None other that I know of.

Q. Suppose that there was difficulty in getting to a dock because the water was low. In your experience is it a fact or is it not, that there would be natural fluctuations in the lake level sufficient to overcome that difficulty within a few hours sometimes and sometimes within a day or two?

A. It just depends on the wind.

Q. And there are frequent variations in the depth of water in the harbors?

A. No, only in the windy season, the early spring or fall, and when we have heavy winds of course.

Q. And during the summer time, sometimes the water is driven away by heavy winds lasting for several hours?

A. It does not affect us very much in the summer. We do not get heavy winds in the summer to affect the levels of the lakes.

Q. I do not mean the lake in general, but at a particular point there might be fluctuations of several inches within a very short time?

A. Yes, not in the summer time, it does not amount to anything; you do not get wind enough to affect the water.

Q. Did you ever know of any of your vessels to be obliged to wait for a change, fluctuations in the depth of water at the Limekiln Crossing?

A. Yes, a great many times.

Q. How frequently in a season would you say that would occur?

A. Oh, I could not tell that. That comes in the early spring or in the fall, when we begin to get heavy weather.

Q. Does it ever occur in midsummer?

A. Yes, I presume it has, but so very rarely that we do not look for it or pay any attention to it.

. . . .

Adjourned sine die.

New York City, May 31, 1911.
1:15 o'clock, P. M.

Parties met pursuant to notice.

Present:

Mr. James H. Wilkerson, on behalf of the Government.
Mr. John C. Williams, on behalf of the Sanitary District of Chicago.

ALLAN HAZEN, a witness called on behalf of the defendant, was first duly sworn, and testified as follows:

Direct Examination by Mr. Williams.

Q. Please state your full name?
A. Allan Hazen.
Q. What is your occupation?
A. Civil engineer.
Q. You reside in the City of New York?
A. I reside in Dobbs Ferry at present.
Q. And your place of business is where?
A. Is in New York City.
Q. In what special line of civil engineering are you engaged?
A. Water supply work, sewerage and sewage disposal.
Q. Will you state the educational training and the practical experience that you have had in the line of your profession?

A. I studied at the New Hampshire State College, and afterwards at the Massachusetts Institute of Technology. From 1888 to 1892, I was at the Lawrence Experiment Station of the Massachusetts State Board of Health; the object of which

station was to determine methods of handling sewage and purifying water.

In 1893, I was in Chicago at the World's Columbian Exposition in the department of water supply, sewerage and fire protection, and operated a plant in which was treated the sewage of the fair grounds before it was discharged into the lake. I also had to do with the water supplies drawn from the lake and other sources used upon the grounds, and was familiar with the water supply system of Chicago.

Q. You were in charge of that work yourself, were you not, at the World's Fair grounds?

A. I was in charge of the sewage disposal plant under the direction of others in the department.

In 1894 I was abroad studying water supply and sewage disposal works; and also studied for a time at the Royal Technical High School at Dresden.

In 1895 and '6, I was in partnership with Mr. Noyes in Boston, as civil engineers, and commenced general work with water supply and sewerage problems, which I have followed since that time; beginning in New York in 1897.

Q. What works have you been connected with or had charge of having to do with the purification of sewage or the protection of water supply?

A. I built a few small sewage disposal works, and have advised in regard to some others; but especially, works at Altoona, Pennsylvania, at Spencer, Massachusetts, Plainfield, New Jersey; a little plant for Vassar College and a plant for the State Lunatic Hospital at Harrisburg.

I have advised cities in regard to sewage disposal problems; especially North Hampton, Massachusetts, Paterson, New Jersey, and I am advising the City of Pittsburgh at the present time.

I have designed and superintended the construction, and advised in regard to a considerable number of plants for purifying water, and have acted generally as engineer for cities and corporations in water supply matters.

Q. Have you acted in an advisory capacity in litigation involving engineering questions along the line of your experience?

A. Yes, sir, I have. I acted for the Town of Millbury in the case with the City of Worcester some years ago, involving the pollution of the Blackstone River. There are quite a number of cases of that kind. I remember being at Gloversville, New York, for the city, with reference to pollutions.

Q. Were you ever employed in any case where the Sanitary District was involved?

A. Yes, sir, I was employed by the City of St. Louis.

Q. That was the case of the *State of Missouri* v. *The Sanitary District of Chicago?*

A. It was, yes.

Q. You are now in partnership?

A. I am now in partnership with Mr. Whipple, Mr. Fuller and Mr. Babbitt. The firm name is Hazen & Whipple.

Q. Has your firm engaged recently in giving any advice in reference to sewage disposal to any city like the City of Chicago, on Lake Michigan?

A. Mr. Whipple has been a member of a commission advising Milwaukee with reference to sewage disposal, and that commission has just reported. I have been familiar with the progress of the work, but have not participated in it personally.

Q. What have you to say with reference to the City of Cleveland?

A. Mr. Whipple studied the water supply and sewerage conditions at Cleveland at considerable length; and I have had to do with those conditions at Toronto through several years.

Q. Having in mind particularly the questions relating to the matter of the purification of water supply, what particular works have you had to do with?

A. I designed and acted as engineer in the construction of the Albany Water Purification Works. I also had charge of the design, and advised with regard to the construction of the Washington, D. C., plant; and have also designed and been professionally responsible for at least a dozen smaller plants.

Q. I think you have already stated that you are now engaged in the City of Pittsburgh?

A. Yes, sir.

Q. Are you familiar with the lake and river conditions in Chicago?

A. Yes, sir, I am, to a certain extent.

Q. Over what period of time has your acquaintance extended, and to what extent have you been familiar with those conditions?

A. I first visited Chicago, I think, about 1889, and was shown the Chicago River which was pointed out as one of the notable institutions of the place. My next acquaintance with the conditions there was in 1893, when, as I have stated, I

spent the year in Chicago; and during that time I saw frequently the river conditions and the conditions along the old canal as far as Joliet and below. And I also was informed as to the water supply conditions existing at that time, and knew of some of them from personal knowledge.

Since that time, I have visited Chicago from time to time and have seen the Chicago River; have been informed as to the lake conditions, the water supply conditions.

At the time of the St. Louis suit, which has been mentioned, I made something of a study of them. At other times it has been simply the study of a very interesting phenomena professionally.

Q. Have you recently made any particular examination of the ground?

A. Yes, sir, during the last week I have been in Chicago; have been through the Chicago River and its various branches; through the Drainage Canal; have visited parts of the Calumet District, and in general looked up the things that seemed significant in the case now at issue.

Q. And from that examination, you are to some extent familiar with the qualities of the water and the effect of the sewage upon the water, at this time?

A. Yes, sir, I think I am.

Q. Are you familiar in a general way with the methods of improving the water supply of Chicago, methods that might be employed, and that are employed?

A. I am familiar with the methods that might be employed, and that are being employed in other cities.

Q. The law under which the Sanitary District is organized provides for the disposal of the sewage of the Sanitary District by dilution at the rate of 20,000 cubic feet of water per minute for each 100,000 inhabitants. I will ask you if you have an opinion as to whether or not that rate is a reasonable rate to ensure the rendering of the sewage harmless and innocuous?

Mr. Wilkerson: I object to that as incompetent, irrelevant and immaterial. The question of the reasonableness of the amount of water authorized by the Illinois statute can in no way whatsoever affect the power of Congress with reference to the matter in controversy.

A. In a general way, the legal amount of dilution is reasonable. The amount of dilution required to prevent the production of objectionable conditions is known within certain limits. Those limits are not absolutely fixed, but depend

upon various conditions, and some of those conditions are complex.

The amount required in this case might prove to be on full investigation a little greater or a little less than is fixed by law. The data that I have been able to collect during the past week, in addition to those that I had before, are not sufficient to determine this ratio precisely. I have a feeling, however, that the legal rate is at least a reasonable approximation to what is actually required for these conditions.

During my stay in Chicago, on May 23d, I went the length of the Drainage Canal and noted especially its conditions; and at my request the chemist of the district went along and made certain tests of things that I wished to know about, and it is my feeling that the water flowing in the canal on that date was carrying substantially as large a load of sewage matter as it was capable of carrying; and the record of flow given me by the chief engineer and the population tributary to the sewer, calculated at my request upon the census returns of 1910 with one year's estimated growth added, indicates that the amount of dilution on that date was very closely that corresponding to the legal dilution.

Q. You mean by legal dilution the rate established by the state law?

A. Yes, sir.

Mr. Wilkerson: 20,000 cubic feet a minute for each 100,000 inhabitants?

A. Yes.

Mr. Williams: You are familiar, are you not, Mr. Hazen, with other methods of sewage disposal, methods other than by dilution?

A. Yes, sir.

Q. Taking into consideration the fact that the Sanitary District has already expended a large amount of money approximating $66,000,000, in building its main channel, and having facilities and plans for the construction of adjuncts and additions sufficient to care for the outlying portions of the Sanitary District, I will ask you to state what is your opinion as to the most economical and appropriate method of providing for the additional sewage that may be produced within the Sanitary District during the coming few years, that is not now taken care of through the main channel?

Mr. Wilkerson: I assume that the objection which I have noted may stand to the whole line of examination, without repeating it for each particular question.

Mr. Williams: Surely.

Mr. Wilkerson: If so understood, I will not interpose an objection to each question, but it may be considered that the whole line of examination is under that objection.

Mr. Williams: I understand.

A. It is my judgment that from the standpoint of the Sanitary District, the most economical and efficient method of disposing of sewage from added population will be by extension of the existing system of dilution and discharge of the sewage towards the Illinois River. I may say that this is based upon general experience and judgment. I have made no detailed estimates of just what could be done in various ways in this case.

Q. That is insofar as the disposal of the sewage is concerned?

A. Yes, sir; but knowing a good deal of the cost of treating sewage, and the difficulties of doing it, I am perfectly clear that it would be much more expensive to treat the sewage so as to purify it and discharge it into the lake than it is to cut canals to carry lake water to dilute it and carry it harmlessly the other way.

Q. In a general way, are there any difficulties that are encountered in the treatment of sewage by methods other than dilutions, in a climate such as we have in Chicago?

A. Why, there are a great many difficulties in sewage purification. Sewage purification is comparatively a new subject. It is a new subject when carried out on any such scale as is represented by the sewage of the Sanitary District. Experience on a large scale is mostly European, and for the most part comes from places where the winter temperatures are not nearly as low as they are in Chicago.

Q. Does low temperature add to or decrease the difficulties?

A. Well, it increases the difficulties of treatment somewhat.

Q. Is there any difference in a general way between the character of the sewage in European cities and that found in American cities?

A. Yes. The European sewage is very much smaller in volume and more concentrated. In other words, the amount of water per capita is very much less, and that facilitates purification of sewage because the large quantities of water with which American sewage is diluted in the sewers render the problem of purification much more difficult.

Q. And also more expensive?

A. And also more expensive.

Q. That is per capita?

A. Per capita; probably would be cheaper per million gallons to treat dilute sewage than strong sewage, but per capita it certainly costs more.

Q. Do you know the amount of water per capita that is consumed in the City of Chicago?

A. The official records show about 230 gallons per capita for the last year.

Q. 230 gallons per day?

A. Per capita per day.

Q. And do you know what the average consumption of water per capita per day in European cities is?

A. It would range from 20 to 30 up to 50 or 60 gallons per capita daily, I should say. London uses about forty.

Q. Assuming that methods other than the dilution method were to be employed by the Sanitary District in carrying off the sewage of the additional territory, and the additional sewage produced which is not cared for by the main channel, what methods in your opinion would be most practicable?

A. I considered three possibilities for disposing of the sewage of an additional population beyond that which could be diluted by 10,000 cubic feet per second, assumed as available for the canal. I assumed as a starting point that that flow will be maintained, and that whatever sewage can be taken care of by it will continue to be so discharged.

It is necessary to state that, because with that as a starting point, the treatment of the rest of the sewage might be a little different from what it would be if that was all that there was to be considered. With that as my starting point, then, it will be possible to take care of the sewage from the added population—

Q. How much added population do you assume?

A. I assume a population of 1,200,000.

Q. That is the population that would be taken care of by 4,000 cubic feet per second, by dilution?

A. At the present legal rate, yes, sir. (Last portion of answer of the witness read, as follows: "With that as my starting point, then, it will be possible to take care of the sewage from the added population"), first by completely purifying the sewage of the added population so that the effluent may be discharged into the lake or into the lake or into the canal as may be most convenient.

Second, it will be possible to provide for it by treating a larger quantity of sewage by partial methods so that the total amount of sewage matter discharged into the canal

would not exceed that in the raw sewage from 3,000,000 people.

And third, it would be possible to let the sewage from the added population go to Lake Michigan through selected outlets, outlets selected I mean with reference to securing good dilution in the lake, and in connection therewith to purify the water supply, to protect it in that way from the polluting matter of the sewage. Which of these three general lines of treatment would be best, it is impossible to state off-hand. Very likely some combination of them would be better than either by itself; adopting each or at least two of them in places where the local conditions might lend themselves to such use.

Q. Assuming the first method were followed, namely, that works be built and operated for the complete purification of the sewage of the population assumed, in your opinion would the cost of such a plant or works be greater or less than the cost of constructing a channel such as is described in the pleadings in this case, having a capacity for a flow of 4,000 cubic feet of water per second?

A. It is my judgment that the cost would clearly be greater.

Q. You have not prepared any figures so as to be able to state to what extent the cost would be greater?

A. No, sir, I have not.

Q. Assuming the second method were employed, and works were built so that the sewage was treated, and the effluent was discharged into the lake, what is your opinion as to whether or not it would then be necessary to install any works for the purification of the water supply?

A. I think it would be desirable and necessary to purify the water in case any considerable amount of sewage effluent were discharged into the lake. It is my feeling that methods of sewage disposal now available to be used reasonably in a case like this are not adequate to protect the quality of drinking water; and if I were running the water supply I should want to protect it from the effects of sewage dilution, and I should look upon the discharge of sewage effluent from any such works as might be reasonably installed at the present time as only in a small degree less dangerous to the water supply than the discharge of crude sewage.

I am taking into account not only the theoretical possibilities of the sewage purification, but all the practical contingencies of operation that do arise in the operation of such plants.

Q. Assuming that the second method were employed, that is, the works constructed for partially purifying the sewage and the effluent discharged into the canal, would such a work or works be more or less expensive than the construction of the channel such as is proposed to be constructed by the Sanitary District, and involved in this suit?

A. Well, I can't say certainly as to that. That involves matters of design and local conditions that would have to be studied out.

Q. It would be necessary in that case to construct some kind of works to carry the effluent to the canal?

A. Oh, yes, that would be necessary. If such works were to be constructed, for instance, in the Calumet District, obviously it would require the construction of a canal similar to that which you propose, although not necessarily the same size. Of course, a sewer, a line through which the effluent was pumped, could be substituted for the canal; but in a locality with a topography like that shown by this map (referring to map spread before the witness), a canal would obviously be cheaper than any pipe line or artificial conduit.

Q. Having in mind the protection of the water supply of the City of Chicago, in your opinion would it be more advisable to discharge the raw sewage of 1,200,000 people into the lake at selected outlets, in the way you have indicated it might be done, and purify the water supply, or would it be cheaper to purify the sewage by the best method that you are acquainted with and allow the water to be used without any treatment or purification?

A. In my judgment it would clearly be better to treat the water and to allow the sewage to be discharged. It would be better because it would be more efficient in protecting the people who use the water from infectious matter from the sewage; and it would be better because it would be cheaper. I mean it is better than trying to purify the sewage and continuing to use the water without treatment.

Q. Are you familiar with the quality of the water now served to the people of Chicago?

A. Yes, sir.

Q. What did you learn in that respect?

A. In addition to my general information as to lake currents and the quality of water obtainable, I visited the Health Department of Chicago and learned what I could as to the character of the water from the different intakes as shown by their records; the water from all the intakes.

Mr. Wilkerson: In addition to the objection already noted,

let this go in subject to the further objection that it is secondary.

A. The water from all the intakes is generally of good quality. At the present time there are times when water of inferior quality is obtained from each of the intakes. The times when water of inferior quality is obtained are more frequent and last longer at the South Shore intake opposite 68th street. This is believed to be due to its being closer to the outlet of the Calumet River which is regarded as the principal local source of pollution of the lake in front of the city at this time.

Q. What effect upon this particular source of pollution would the construction of the Calumet Sag Channel and the reverse of the flow of the Calumet River have?

A. It would clearly tend to reduce this source of pollution.

Q. And suppose further that intercepting sewers were constructed to divert the sewage that otherwise empties into the river, so that it would empty directly into the canal, what effect would that have?

A. If the interception were carried to completeness, it would practically eliminate this source of pollution.

Q. Assuming, Mr. Hazen, a population of 1,200,000 people, producing sewage which is cared for by the construction of a channel with a capacity of 4,000 cubic feet of water per second and by the construction of intercepting sewers such as we have assumed in the preceding question, so that no part of the sewage of that population emptied into the lake, what is your opinion as to the necessity in that case of constructing purification works for the purpose of purifying the water supply of the city; and if such works are necessary, of what character should they be?

A. Under the assumed conditions, I believe that it would be reasonably sufficient to treat the water with hypochlorite of lime. I believe this treatment would be advantageous at the present time, and I should regard it or its equivalent as reasonably necessary under the conditions that you mentioned.

Q. What other sources of pollution are there other than the sewage which ordinarily empties into the Calumet River and the Chicago River, which would render it necessary to install purification plants?

A. There is pollution from shipping, from the dumping of various waste materials into the lake; from the sewers of other cities and towns, and there is almost certain to be

sometimes some overflow from the sewers in times of unusual rains.

Q. Have you made an estimate of the cost of such works as you have described for the treatment of the water supply of the City of Chicago by the hypochlorite system?

A. I considered the cost on the basis of the present works and the present amount of supply. I have made no very detailed estimates of the exact works, but I know from other cases some thing of what would be involved.

The cost of installing the works would not exceed $100,000; and the cost of operation for the present quantity of water may reasonably be estimated at about $60,000 per annum. The works for applying the chemical not being of the most permanent nature, I consider that 20 per cent. of the cost of construction might be taken as the annual charge, or $20,000 for the works and $60,000 for the operation, making $80,000 per annum as about the fair cost of treating the present supply of water by this method. These cost figures would increase proportionately or nearly proportionately with the amount of water drawn and used.

Q. Assume that the sewage of a population of a million two hundred thousand people were discharged in its raw state into the lake, what purification works would you then consider as proper and necessary for the protection of the water supply of the City of Chicago?

A. I consider that with such a discharge of sewage into the lake it would be desirable and reasonably necessary to filter the water before use; and I should use the hypochlorite treatment of the effluent from the filters.

The works proposed would correspond with those now being built by the City of Toronto to meet very similar conditions. The present use of water is five hundred and twenty million gallons per day. I assume that filters would be required with a nominal capacity of 40 per cent. in excess of this amount, to cover fluctuations in rate and to provide a reserve for units out of use, for cleaning or other purposes. This would call for about 120 acres of filters, operating at a rate of 6,000,000 gallons per acre daily distributed among the different intakes in proportion to capacity. These filters could be built on the lake shore, or on cheaper low lying land back of the lake shore, and not too far away from it; or just as well in shallow water near the shore.

Low lift pumps would take the water from the present tunnels to the filters and the effluent would go back into the tunnels beyond. The conditions of construction seem to be gen-

erally similar to those met at Toronto; and I am basing my idea of cost upon the prices actually being paid at Toronto. Upon this basis, the cost of the works complete with all connections with the present works, but exclusive of land, would cost about $10,000,000. The cost of land would have to be added.

I know about that only by inquiries of the most general kind, in connection with some knowledge of topography in the various locations; and I assume that the sites might reasonably cost $3,000,000, making the total cost of installation about $13,000,000.

The annual cost of operation I estimate at about half a million dollars. Both the cost of construction and operation, of course, would increase in the future in proportion or nearly in proportion to the amount of water drawn and used.

Q. If this system were installed and these works constructed, in your opinion, would it be necessary to install any additional works; would the hypochlorite system be reasonably necessary in order to render them perfectly efficient?

A. Well, I have included that in my estimate and in the statement. It would be necessary to have some added works to prevent offensive conditions in the Calumet River.

Q. Assuming that the sewage of the population assumed was completely diverted and treated by dilution through a channel such as is proposed to be constructed by the Sanitary District, and the hypochlorite system of treatment was adopted; then assume that the sewage was emptied in its raw state into the lake and the system last described by you were employed for purification of the water supply. Which would produce, in your opinion, the better result from the standpoint of purity of water?

A. As near as I can tell, or estimate ,the conditions would be about equivalent, as measured by the sanitary quality of drinking water produced.

Q. In your opinion, what would be the effect upon the lake and upon the Calumet River itself, if the sewage of 1,200,000 people in its raw state were emptied into the river and into the lake so far as producing nuisance is concerned?

A. I think the sewage of 1,200,000 people discharged mainly into the Calumet River would produce offensive conditions in it, which conditions would require some local treatment.

Q. Have you given any thought to any treatment that might be applied to obviate the nuisance thus created?

A. Yes, sir, I have given the matter some thought. In a

general way it would seem that the method of flushing that has been used by Milwaukee through a long term of years would be the best way of correcting such conditions in the Calumet River; I mean the best way looking at it as a local problem and excluding the channel which you are proposing to build.

Q. We are assuming that the channel is not built. Can you describe a little more in detail the flushing system to which you refer?

A. The flushing system at Milwaukee consists in cutting tunnels from the lake to points on the river above the points where the objectionable conditions exist and pumping water through the tunnel to produce a current in the river and to dilute the sewage discharged into the river to such an extent that it will not become objectionable.

Q. And also creating a current?

A. It also creates a slight current. The first of these tunnels was built in Milwaukee, I think, something like twenty years ago. A second one was added fifteen years ago. And a third and a more expensive one has just been recommended, as the conditions in parts of the stream are bad at the present time.

Q. Have you, from your investigation, an opinion as to what such a system would cost, if it were to be constructed and put in use in the Calumet River, assuming that the channel proposed is not built and the sewage became a nuisance in the river?

A. The first two tunnels and works at Milwaukee cost approximately $750,000. They have served their purpose well, but seem to be outgrown at the present time. The estimated cost of the canal recently recommended is about $1,150,000, which would bring the whole cost of the works to $1,900,000. Taking into account the fact that the two canals as built seem to be somewhat overtaxed, and the fact that the new canal anticipates growth, three dollars per capita for construction seems to be about a fair figure. And the cost of operation, which is made up mainly of pumping water, at Milwaukee seems to run from ten to fifteen cents per capita per annum.

Q. In your opinion, would those figures prevail substantially in the Calumet region if the same system were employed?

A. Why, I should suppose they would within certain limits. Of course tunnelling conditions may be more favorable or less favorable. I have not looked into that. It was my

feeling that what Milwaukee had actually spent was perhaps the best off-hand guide that I could get as to what Chicago might reasonably spend in this case.

Q. And in your opinion that is a good guide?

A. Yes, in a general way.

Q. Taking into consideration, Mr. Hazen, the fact that the Sanitary District has thus far proceeded to dispose of the sewage of the district by the dilution method and by the construction of channels, I want your opinion as to the advisability of either changing the system or attempting at this time to supplement the works that are already constructed by an entirely different system; and if such attempted substitution or addition were made, what would be the effect on the present sewerage system of Chicago; the costs and difficulties involved; not having in mind the figures at all, but the general wisdom of the substitution or change?

A. I think it would be very unfortunate to have to change the system at this time. The whole theory of the present system, as I understand it, has been to dilute the sewage matter as promptly and as largely with water as possible. To treat the sewage so as to purify it artificially in a chemical way involves carrying out the reverse system; that is, treating the sewage matters with as little dilution as possible up to the point where the sewage is treated. The whole district is sewered on the combined system; that is to say, all the rain water and street wash is carried to the sewer and flows in the same channel with the sewage matters. To completely and economically treat the sewage, it is necessary or at least very desirable to have the separate system; that is to say, to keep the sewage matters from mixing with the street wash and rainwater.

In order to treat the sewage thoroughly, adequately to its logical conclusion in any new district would mean the installation of separate sewers in place of the combined sewers, and this would involve a very great added expense. It is partly for that reason that it seems to me that a partial treatment of a larger quantity of sewage might have great advantges in connection with the present authorized flow rather than the complete treatment of all the sewage from a certain separated population. But certainly to change the system now would involve readjustments that would cost the district a great deal of money.

Q. If a separate sewerage system were constructed, in order to separate the sewage proper from the street washings and the rainwaters, those street washings would then flow

where, Mr. Hazen, assuming that this channel were not constructed through the Calumet region, and assuming that we are dealing with the Calumet region?

A. I presume that would flow to the Calumet River and ultimately to the lake.

Q. What effect would they have upon the purity of the water supply?

A. They would tend to pollute it.

Q. Will you state, Mr. Hazen, from your experience, what length of time it takes for fresh sewage to become putrified so as to become a nuisance?

A. I don't think there is a fixed limit on that. It is a question of temperature to a considerable degree. I can state my observations in going down the canal on May 23d as bearing upon this point. The mixture flowing in the canal after passing Western avenue must have been substantially the same that it was from that point all the way to Joliet; but in the upper part of the canal, that is to say, at Western avenue and for a few miles beyond, the sewage was comparatively fresh. There was plenty of dissolved oxygen in the mixture and the conditions were entirely unoffensive. Going down the canal, the amount of dissolved oxygen was steadily reduced and it was almost exhausted before the powerhouse was reached. The putrification of the sewage was apparent in the last miles; and there were evidently beginning to be deposits of sewage mud along the edges at several places, and especially in the fore bay at the power house. The mixture was almost up to the point of becoming offensive. This was especially interesting to me as showing the effect of time for these changes to take place. There was no increased pollution at the power house as compared with Western avenue of any practical significance, but there was a great increase in the effects of pollution.

The passage of the mixture by the power house partially aerated it, and considerably improved its appearance, so that it was in better shape below and in Joliet than it was right at the power house. Under the conditions of flow and temperature existing on this particular time, the greatest apparent effect of pollution occurred just above the power house. I can imagine, however, that with other temperature conditions, other conditions of flow, the maximum might occur at some other point.

Q. Suppose, then, Mr. Hazen, that the population of Chicago, that part of Chicago which sewers into the Chicago River, should substantially increase beyond the amount that

can be properly cared for by the dilution method according to the rate now prescribed by law, what would be your opinion as to the advisability of constructing a channel to discharge the water into the main channel at a point somewhere between Chicago and Joliet, for the purpose of further diluting the sewage as it proceeds down the channel?

A. It is my feeling that looking through a reasonable period of years, controlling points on the necessary amount of dilution will be at Joliet and in its neighborhood, and in the valley for some distance below; that through the closely built up part of the City of Chicago it is more a matter of time than a matter of dilution, and that with a sufficient current, meaning by that a current not less than the present current, the materials may be carried along—will be carried along so as not to become especially offensive in that part of the city, and with respect to these lower conditions, which it seems to me are going to be the controlling conditions in such a period of years, the mixture of water coming through this proposed Calumet Canal will be almost as useful as a corresponding quantity of water coming down the river all the way. Of course, if all the conditions permitted it, it would be better to have it come with the sewage all the way.

In speaking of the present current in the river, I referred to the current in the main stream. There is part of the North Branch where under the conditions on May 23d, the current was less than it ought to be; but there are new works under way that I understand will increase that.

Q. In your opinion, Mr. Hazen, is it desirable or necessary in order to properly treat sewage by the dilution method to have a current, so that the sewage is constantly in motion?

A. Why, yes, sir, I regard that as almost essential. If you have an extremely large dilution, it may do to put the sewage into quiet water; and on the other hand, if the available current is very strong, it is my feeling that the dilution may be a good deal less. I think there is a relation between the strength of current and the amount of dilution, and the stronger the currents, referring to the currents not only at the point of dilution, but all the way to the point where the sewage is disposed of, the dilution may be less than where the currents are sluggish.

Q. You have described your observations on May 23d, as to when you first noticed the putrifaction of the sewage. Can you state any more definitely how soon after you left Western avenue, that is, how short a distance from Western avenue, that condition first manifested itself?

A. It was manifest first in the chemical analysis in the determination of dissolved oxygen; that was going down steadily. But I can't say that I noticed much difference apparent to my senses until we had gone down the canal quite a long ways; and it increased most markedly within two or three miles above the power house.

Q. And what was the temperature on that day; that is, generally speaking, was it a warm day?

A. Yes, sir, it was a warm day.

Q. Would it make any difference, Mr. Hazen, in your opinion, as to where the point of putrifaction would become first appreciable to the sense as to what the temperature was; I mean having reference now to the chemical analysis?

A. I think it would. I think the temperature of the water would have more influence than the temperature of the air; and the highest temperature in the water would occur later in the season, in August or about the first of September.

Q. Would the putrifaction be noticeable—I am speaking now to the sense of smell—when it was warm sooner than when it was cold?

A. I should expect that it would occur sooner in the higher temperature. It is possible that to off-set that condition—I have observed that in Pittsburgh—where the discharge of certain kinds of manufacturing waste seemed to have the effect of stopping the putrifactive processes for the time being; and considerably postponing the point where the worst conditions appear; so the temperature does not necessarily alone control.

Cross-Examination by Mr. Wilkerson.

Q. Just what was the nature of the work which you did in the Lawrence Experiment Station?

A. We had experimental filters of various materials, of various depths, and to these we applied sewage, raw sewage, settled sewage and water of various kinds, in the endeavor to find out how sewage and water could be best purified, especially with reference to the conditions existing in the State of Massachusetts; and many other experiments along allied lines relating to the qualities of public water supplies and the methods of protecting them were carried out. It was an experiment station for the State of Massachusetts.

Q. It was for the purpose of finding out how much the water could be polluted and at the same time be taken care of by the filters?

A. Well, that is one line of investigation.
Q. Was that the principal line?
A. No, I should not say it was the principal line.
Q. What other lines were there?
A. The principal lines, that is your question?
Q. Yes.
A. They were to find the best available methods for taking care of sewage and water supplies in the state.
Q. And as the result of your work, was there any conclusion reached as to the best method?
A. Many important conclusions were reached. The work was not carried to the point of selecting any one method as being pre-eminent over others. That would hardly be possible, because there are different conditions that require different methods; and the work was rather to show what could be done by different methods under different conditions than to select one that was better than all others.
Q. Now, what was the nature of the plant that was constructed at Chicago during the World's Fair, which you spoke of?
A. That was a plant for treating the sewage by a process known as chemical precipitation. There is a description of the plant in the report of the Massachusetts State Board of Health for 1893, page 597.
Q. Give us just in a general way the main features of the plant and the method which was used?
A. The settling tanks were of the so-called Rockner-Rothe type. This was a German type tank which had recently been brought out and represented probably the most advanced practice and ideas at that time. There were four of these tanks. The sewage was first screened; then was treated with chemicals and went to the bottom of these tanks, the sludge deposited in the bottom; the sewage rose and overflowed weirs at the top and went to the lake. The sludge was drawn up from the bottom of the tanks from time to time; was pressed, and was burnt in a crematory near by.
Q. It was the intention that the sewage should be treated in such a way as not to pollute the waters of the lake, was it?
A. That in a general way was the intention.
Q. Was it successful?
A. The effluent, I think, produced no local nuisance around the discharge. So far as its effect upon water supply was concerned, the treatment might just as well not have existed.
Q. So far as the water supply was concerned?
A. So far as the water supply was concerned. In other

words, the treatment did not stop the bacteria representing any infectious material, which there might have been in the sewage.

Q. So it was more for the sake of getting rid of the offensive local condition that this was done?

A. That is what it accomplished. When you speak as to the intention, that goes somewhat back of my connection with the work. The World's Fair wanted to have everything up to date, and the best of everything; and they wanted a sewage disposal plant and they got it. I suppose that the people when they decided to build the plant expected that it would protect the water supply from any pollution that there might be in that sewage, but as a practical proposition it did not do that thing.

Q. Now, how many people did they have in mind in the construction of that plant as being taken care of?

A. The population tributary to the works is stated in the report mentioned on page 618. The greatest number of people was in October when there was a total attendance of 8,034,000 within the grounds.

Q. That is the whole month?

A. That is the whole month. In September there were 5,809,000. I could not say as to what number of visitors was contemplated in advance. This is a record of the number of visitors that there were.

Q. You say that the method which was used there did not result in destroying the bacteria?

A. It did not destroy them.

Q. It did not?

A. No, sir.

Q. Was it supposed that it would when the plant was constructed?

A. Well, I can't say as to that. The plant was authorized and started before I went to Chicago.

Q. Do you know how much the plant cost?

A. I, of course, knew from my experience at Lawrence that that method would not be efficient in stopping the bacteria. I doubt if many people in the department really knew that until they got the results. I can't tell you exactly what the plant cost; it is my impression it cost something like eighty to one hundred thousand dollars.

Q. What was the cost of operation?

A. Here I have it (referring to report). The cost of construction was $55,000; but I would say in regard to that that quite a part of the equipment was contributed as exhibits, so

that the fair cost of building it would have been considerably more than that.

Q. What would you say would be the fair cost of building it?

A. The machinery was nearly all contributed as exhibits. I think the figure I first gave you would be as nearly as I could tell you. The cost of operation from April 14th to October 27th was $14,207; 373,000,000 gallons of sewage were treated.

Q. Is that method used any more?

A. Yes.

Q. Where?

A. Providence, Rhode Island, uses it; the biggest sewage disposal plant in the United States.

Q. How long has it been in operation there?

A. I should think a dozen years, perhaps longer.

Q. Does this report to which you refer state that that did not result in destroying the bacteria?

A. It shows it.

Q. It is your report, is it?

A. Yes, sir.

Q. And the Providence plant was built after that time?

A. Yes, sir. I don't think the Providence plant was intended to remove the bacteria; I am sure it was not.

Q. What was it intended to do?

A. To keep the sewage sludge out of the bay.

Q. Is a plant of that kind in use any place else?

A. At Canton, Ohio, they have a plant of that kind, that I think is in service. Worcester, Massachusetts, has a plant of that kind; but in the last years, the greater part of he effluent from it has been subsequently filtered; but the chemical precipitation part of the plant is still operated. Plants of this description were used very generally in Europe at this time. I think it was the most widely used method of treating sewage at that time, perhaps in the whole world.

Q. At that time was it generally supposed that that method would destroy the bacteria?

A. It certainly was not in Europe, because the European plants as far as I know were not any of them intended to remove the bacteria. They were intended to remove the sludge which otherwise produced objectionable deposits in the rivers and channels; and the European engineers and chemists that I knew in charge of these plants were under no illusions in regard to their lack of bacterial efficiency.

Q. You say you studied in Dresden for a year or two?

A. No, for a semester—a term.

Q. Along the same general line of work that you had been doing at the Lawrence Experiment Station?

A. I took the course of Wasserbauer as they call it, water works construction, hydraulic construction.

Q. Now, you have spoken of some plants with the construction of which you have had something to do. You spoke of one at Altoona, Pennsylvania?

A. Yes.

Q. What kind of a plant have they there?

A. That was what was called intermittent filtration of sewage. A large sandy tract of land was taken and cut up into beds and underdrained; and the sewage is applied to that during the summer and crops are raised upon it, so that it is a partial irrigation.

Q. For what sized population was that plant intended to provide?

A. The population of Altoona, as I remember, is forty or fifty thousand, and this plant serves rather more than half the city. The other half of the city drains in another direction to another stream.

Q. What did that plant cost?

A. I should have to look up my records.

Q. Have you any general idea on the subject? I do not care for the exact figures.

A. Well, I should think $100,000.

Q. And what would be the cost of maintenance?

A. Well, probably $1,000 a year.

Q. And in order to provide for a larger population, would the cost be proportionately greater?

A. It would be if there was more sandy land, but we took all the land there was available.

Q. You have to have sandy land?

A. You have to have sandy land in order to do it.

Q. If you have lots of sandy land that kind of a plant works all right?

A. That plant worked all right. That is why substantially the same kind of plant has worked so well at Paris and Berlin.

Q. So if you had whole counties of sand that could be put in operation very easily?

A. That would be first rate, barring the transportation. I may say in regard to this Altoona plant, it is intended to treat the sewage in summer when it is otherwise objectionable in the stream. The process does not work very well in winter and I have never considered that it was necessary to treat

that sewage in the winter, and have advised them to bypass the plant and let it go through the winter.

Q. What kind of a plant was put in at Spencer, Massachusetts?

A. That was similar in its general character to Altoona; treated the sewage of the whole town. The sand was coarser and better at Spencer than Altoona.

Q. Was that as large a plant as the Altoona plant?

A. Not as large in area; not as large in any way, because the population was smaller.

Q. Was the plant at Plainfield the same kind?

A. That was, but Plainfield has grown rapidly and the sandy area not having grown, the plant has been rebuilt and modified since I had to do with it.

Q. You say you have acted in an advisory capacity to the City of Pittsburgh?

A. Yes.

Q. During how long a time has your employment continued?

A. I took that work up a year ago last January.

Q. Did they have in contemplation there the construction of a new system, or was it with reference to overhauling the old one?

A. It has been proposed to reconstruct generally the sewer system of Pittsburgh, with the object of taking the sewerage to one place and treating it before discharging it into the Ohio River. The whole question of the expediency of doing that and the methods to be followed, is being investigated.

Q. Has any conclusion been reached on that subject?

A. No conclusion has been reached.

Q. Have you reached any conclusion?

A. Not officially; I have personally.

Q. Well, without committing yourself in any way that would prejudice your employment there, just what are the available methods of handling the sewage?

A. I can tell you what the available methods are.

Q. I suppose what it is desired to accomplish is not to pollute the waters of the Ohio River?

A. Yes.

Q. To save the water in the river from that pollution?

A. Yes.

Q. So that the sewage will be treated before it reaches the river, so that it will be inoffensive?

A. That is the idea.

Q. Now, what is the general scheme that has been worked out with respect to that?

A. Several general schemes have been worked out.

To go back to your preceding question as to what the possibilities are, there is first the possibility of the present conditions where all of the sewage collected in the combined system and mixed with all the rainwater and street washings goes to the river at the nearest point. The first possibility of improvement consists in taking the dry weather flow from the larger sewers and taking it through settling basins to remove the heaviest part of the sewage mud and to prevent the deposit of sewage mud in the shallow water along the shore of the river at low water, especially between the shipping and the shore. That method of treatment is directed to correcting the physical appearance of the river opposite the city. That is the method that is usually used by cities in continental Europe. It has not been adopted in America to any appreciable extent. It is not directed at all to protecting the river water below from pollution with respect to water supplies.

The next possibility that may be mentioned consists in the collection of all the sewage at some central point where it might be treated and purified before being discharged. This involves in the first place installing a separate system throughout the city in place of the combined system, at a cost of untold millions of dollars. It is a very expensive operation and it is absolutely essential because no plant can possibly be built that is capable of carrying off the storm overflows from a city like Pittsburgh. The storm overflows from Pittsburgh are larger in proportion than in Chicago because the topography is abrupt and the run-off is quicker.

After the present sewers were all built over on a separate system, then great intercepting sewers would be built down each side of each of the main rivers to some central point, or some point below the city, rather, where a site may be selected, and where the sewage would be pumped to bring it from the low level which it had reached by its gravity flow up to an area where the disposal works would be built, above ordinary floods; and there works would be built on some system to purify it.

Q. Aside from the cost of reconstructing the system of sewers, have you reached the point of making any estimates, as to the cost of the purifying works?

A. Such estimates are in process of being made, but I am not in position to announce any results as yet.

Q. Are you able to give us a general idea as to the limits within which the cost of such a work would fall?

A. It represents a great many million dollars.

Q. Are you able to give any more definite an estimate than that?

A. No, I could not state it any more definitely.

Q. When you say a great many, do you mean more than ten?

A. The whole plant represents a good deal more than ten.

Q. I am speaking not of the reconstruction of the sewers but simply the purifying plant itself?

A. I could not state as to that.

Q. How large a population are you attempting to provide for?

A. The present population is about a million.

Q. How much growth are you anticipating in planning the plant?

A. We laid these works out for about double the population.

Q. About two million?

A. Pittsburgh is growing quite rapidly.

Q. You could not give an approximation, or what you believe such a purifying plant would cost to construct?

A. No, I could not. I could give you corresponding figures for Paterson, New Jersey.

Q. Let us have those?

A. Where the estimate was completed?

Q. For how large a population were you attempting to provide there?

A. The population of Paterson in 1905 was assumed to be, at that time, 111,000. The population contemplated in the estimates was 250,000, of which a part of the construction was to be postponed. The whole cost of the purification works was estimated at $3,028,000, of which $600,000 could be postponed for a time; and the cost of the works to be built at once was $2,428,000. That does not include the cost of separating the sewers. Paterson was sewered on the combined system, and this estimate did not contemplate an immediate and complete separation, but only the separation of the larger areas at once, to be followed up with a gradual separation of other areas. I find that I allowed $550,000 additional for separating surface drainage.

Q. I think you said you came in contact with this Chicago problem in the litigation between the Sanitary District and

the City of St. Louis, with reference to the pollution of the water?

A. I did.

Q. You were a witness for the City of St. Louis?

A. I was.

Q. And then had occasion to look into the effect of the discharge of sewage through the Drainage Canal, down through the Illinois River and into the Mississippi?

A. Yes, sir.

Q. And what conclusion did you reach about that?

A. I reached the conclusion that the sewage of Chicago was an undesirable addition to the St. Louis water supply.

Q. That was before it was treated?

A. The water was used as it came from the intake at that time.

Q. That was at St. Louis?

A. That was at St. Louis.

Q. That is to say, you reached the conclusion that the effect of the taking of this sewage from the Chicago Drainage Canal down through the Illinois and Mississippi Rivers polluted the water supply of St. Louis?

A. I believed it did. It certainly tended that way.

Q. It was your conclusion as an expert in the case that it did have an effect of polluting the water?

A. I believe it did.

Q. That was the effect of your testimony, was it not?

A. (No response.)

Q. Now, you have had to do with the construction of a plant at Washington, did you say?

A. For treating the water.

Q. Treating the water?

A. Yes, sir.

Q. What is it necessary to do there? What was done; just what was the plant constructed there?

A. The water is taken from the Potomac River. It flows from an intake above Great Falls through three reservoirs in which a considerable amount of mud is deposited. Before the plant was built, it was pumped directly from the last of these reservoirs into the mains, or flowed to some of the lower parts of the city by gravity.

The plant is a plant for filtering the water. It consists in passing through sand; the water is pumped from the last of these reservoirs to twenty-nine filters of sand and covered with masonry structures; and the water passes through the sand and is collected underneath and carried through suitable

works and conveyed to the distribution. The works are similar in their general nature to those which I suggested being used in treating the Chicago water, in case sewage were discharged in large quantities into Lake Michigan; but differ in many details because the Potomac water is different in its character from Lake Michigan water, and requires within certain limits a different kind of plant to handle it.

Q. Was the problem there a more difficult problem than the Chicago problem, assuming all the sewage was discharged into the lake?

A. Yes, I think it was.

Q. It required a more expensive plant than would have been required at Chicago?

A. More expensive per million gallons, yes; of course, not as large, not as expensive in the aggregate because Washington is not as large as Chicago.

Q. And for how many people did you undertake to provide in the construction of that plant?

A. Oh, we figured it to provide so many million gallons. The question of how many people depends upon how many gallons per capita they use.

Q. How many million gallons did you have in mind?

A. The consumption at Washington has decreased a good deal in the last years by cutting off useless waste, and the consumption is a good deal less now than it was when we first took this work up. The plant was built to treat eighty-seven million gallons of water per day, but it is actually capable of treating a somewhat larger quantity.

Q. Do you know how much that plant cost?

A. It cost about $3,300,000. That is a higher cost per million, no doubt, than I figured for Chicago, because, as I stated, the conditions are different and at Chicago I assumed that we should use a rate of 6,000,000 gallons per acre daily, which is the rate that we are proposing to use at Toronto and they actually use in some other cases.

Q. You are speaking of some estimates that you made for Chicago; when did you make them?

A. In this testimony. The Washington filters were only designed to operate at half that rate.

Q. Now, with reference to this study of the lake and river conditions at Chicago, which you made last week, at the time you made this study, how much water was being diverted from Lake Michigan through the Chicago River?

A. The quantity as calculated at my request from the

records available on May 23d was 421,311 cubic feet per minute.

Q. You spoke with reference to the amount authorized by the law of Illinois as 20,000 cubic feet per minute for each 100,000 inhabitants, and with reference to the reasonableness of that amount. Now, on the basis of the present population of the City of Chicago, how many cubic feet per minute were being diverted from Lake Michigan through the Drainage Canal, at the time you made these observations?

A. I took the population as 2,200,000, which was obtained by taking the population by districts according to the census of 1910, as Mr. Pearse worked it out, and adding the estimated normal growth for one year; and it came a few short of that, but we rounded it out, and it was 2,200,000. That would make 19,200 cubic feet per minute per 100,000 of population. I regard these as approximate and not exact figures.

Q. Did I understand that you had made an estimate of the cost of constructing the plant for treating the water supply of the City of Chicago on the basis of its present population?

A. Yes, sir.

Q. And what was the figure which you gave? This is assuming, of course, that all the sewage goes into the lake, and the water has to be treated?

A. Assuming that the sewage from an added population of 1,200,000 goes into the lake?

Q. No, I am speaking now of the cost of treating the sewage on the theory that it was all emptied into the lake, and that you closed up the present channel.

A. I have not made such an estimate.

Q. You have made no such estimate as that?

A. No.

Q. You made an estimate of the cost of treating the water supply on the theory that the sewage from 1,200,000 goes into the lake?

A. Yes, sir.

Q. Would it require a very much more expensive plant to treat the water supply, if the sewage from two and a half million went in rather than 1,200,000?

A. Well, that would depend largely upon the points that were available for the discharge of the sewage. It would be much more difficult and more expensive to get outlets for the sewage with the larger population which would be as well diluted and no more injurious to the water supply than it would to secure such outlets for a million two hundred thou-

sand population, which population naturally would be extra population and largely at the extremeties of the city as distinguished from the central part of the city.

Q. This computation which you made was on the theory that this 1,200,000 population is in the neighborhood of the Calumet River. What I am trying to get at is the exact elements that have entered into that computation?

A. I assume that it might all enter from the Calumet district, or that any part of it might enter from a somewhat similar district to the north, where it might be more convenient to let part of the sewage go.

Q. And you have made a computation on the basis of the sewage of 1,200,000 people?

A. Yes, sir, that is to say, I assumed that that amount of raw sewage was going into the lake.

Q. And have you made a computation having in mind the present approximate population of this Calumet district? What is that figure?

A. The estimated population now connected with sewers discharging into the Calumet River is 131,000; that is wholly within Illinois. And in addition thereto there are about 50,000 people in Illinois not connected with the sewers, on the best available data; and in Indiana there are estimated to be 97,000 people.

Q. Now, let us assume that this canal here connecting with the Calumet River is not permitted to be constructed, and that the sewage which is now going out through the Calumet River has to be provided for in some other way. Having in mind, we will say, that the population of the district is double what it is now and allowing for that element of growth, just what could be done in the way of taking care of the sewage of that district?

A. I should say that the first step would be to filter the water supply.

Q. That is to filter the entire water supply of the City of Chicago?

A. I should say so, starting perhaps with the south crib and working north.

Q. Well, wouldn't it be possible to treat the water that empties into the lake in some way so as to render it inoffensive?

A. Treat the sewage, you mean?

Q. Treat the sewage, yes?

A. It would be possible to do that, but in my judgment it

would cost more money and be less efficient than treating the water.

Q. How could the sewage be treated? I am speaking now of, say a population of 300,000 people, assuming that there were 300,000 people around that river?

A. It could be treated as was proposed for Paterson and as has been done at Columbus and other cities, by collecting it in intercepting sewers, by pumping it, by settling out the heaviest of the sludge, by screening it, by applying it to sprinkling filters; by settling again the effluent from the sprinkling filters to cut out the heaviest part of the mud, and finally by disinfecting the effluent with hypochlorite of lime. All these processes are successive processes, not alternate ones.

Q. What would be the result assuming that method were followed as to the condition of the water which would go into Lake Michigan?

A. If all the processes were carried out perfectly, and if all of them worked all the time, it would remove very much the largest part of the organic polluting matters, and the largest part of the bacteria, but it would not remove all of them.

Q. Would it then be necessary to filter the water?

A. I should say so.

Q. That is, you think even if that method were resorted to, you would still have to filter the water, at least from the Hyde Park Crib?

A. From the standpoint of water supply, I should make very little difference in the required treatment whether the sewage was treated before discharge or were not so treated. In other words, I do not believe that the methods of sewage treatment now available in a location of this kind are to be fully relied upon to protect the water supply.

Q. In the estimate which you made, you had in mind the population of 1,200,000, that is, the sewage from a population of 1,2000,000 people?

A. Yes.

Q. Have you made any estimate of the cost of filtering the water, assuming that the sewage of only one-fourth of that number of people emptied into the lake?

A. No, sir, I have not.

Q. That is 300,000. What difference would that make in the estimated cost of filtering?

A. It would not make a very large difference.

Q. Would it reduce it?

A. It would tend to reduce it, yes.

Q. Would there be the same necessity for filtering the entire water supply of the City of Chicago if the sewage of 300,000 instead of 1,200,000 emptied into the lake?

A. There would not be the same degree of need of filtering, certainly.

Q. Would you have to go any further north, in your opinion, than the 68th street crib, if the sewage of only two or three hundred thousand people emptied into the lake, in filtering the water, or would it be sufficient to simply filter the water that was taken in at that crib? I am assuming now that all that goes into the lake is from the Calumet District?

A. Yes.

Q. Instead of 1,200,000, you have only two or three hundred thousand people?

A. Discharging here (indicating on map)?

Q. Discharging there, and that is all that goes into the lake?

A. Yes.

Q. And having in mind that the water supply is taken from different places all along the lake shore. I am trying to get your best judgment as to how much of the water supply you would have to filter, on the basis of two or three hundred thousand people in that territory?

A. It is clear that all of the water ought to be treated, but it may be that from the northern tunnel water would be obtained which for the present would be of sufficiently good quality with simply the hypochlorite treatment carefully administered; and that might be true of some of the other tunnels, with the smaller population.

Q. That is, you think that with the hypochlorite treatment you could on the basis of merely two or three hundred thousand people, down there discharging sewage into the lake, you could remedy the difficulty with respect to a considerable portion of the water supply?

A. It would improve the situation very much, certainly. We have found that at Toronto where unfortunately there was a break in the intake during the last winter, and where temporarily water has been taken of much more polluted character than is ordinarily used, we have found that by following out the hypochlorite treatment very persistently and carefully, the results have been very satisfactory.

Q. Now, with respect to this water at the 68th street crib, you went out you say with a chemist?

A. No, sir, I did not go out to the 68th street crib.

Q. Just what examination did you make of that water?

A. I only examined the records of the Health Department at this time.

Q. That was on the 23d of May?

A. Yes.

Q. And the records which you saw showed what with reference to that water at the 68th street crib?

A. The greater part of the time the water is of as good quality as the water from the other tunnel, but occasionally it falls off in quality very much, so that it cannot be considered good water.

Q. How much of the time is that?

A. I cannot state the extent of the time. That is a matter of degrees. It falls off a little in quality for longer periods, and falls off a great deal in quality for shorter periods.

Q. Of course there are always some bacteria in all water, and it is a matter of degree as to when the water is safe to drink?

A. Yes, that is true.

Q. It is hard to fix the absolute limit, where we know that water is safe to drink. It is difficult to get absolutely safe water?

A. I should say there was such a thing as absolutely safe water, practically safe.

Q. What I was trying to get at was, in as specific form as we could get it, just what and to what degree there is anything wrong with that water there at the 68th street crib?

A. This pollution is most effective when the wind blows the water directly in that direction. (Indicating on map.)

Q. That is north?

A. Yes. They tell me that at the Health Department; but I also know that from my experience with lake waters in other cases. The wind may blow it up here (indicating) on one day, so that it comes up and there is a good deal of pollution, and then the next day the wind may blow from some other direction and the water is of quite different quality. It is possible for the character of the water from a lake intake of this kind to entirely change its character in a half hour.

Q. When you spoke of the wind blowing, you meant blowing from the Calumet River?

A. Towards the intake.

Q. North towards the intake?

A. Yes, sir. I do not know as I completed the answer to your question.

Mr. Wilkerson: Pardon me.

The Witness: Having seen these records and knowing something of the pollution of lake waters and their subject to these influences, I can put it this way: If I lived in territory served by that intake, I should not want to drink the water without having it boiled.

Q. Or filtered?

A. Or filtered, yes, sir.

Q. Now, has it not been considered possible to take the sewage of this Calumet region here and dispose of it in some other way than by discharging it through the Calumet River, or have you given any consideration to any such plan as that?

A. I considered the possibility of collecting this sewage and treating it in the way that I mentioned a few minutes ago, and it certainly could be done. Treating the sewage of Milwaukee in that manner was considered by the Commission of which my partner was a member, but it was found on the evidence that they had that it was clearly better to discharge the sewage at selected points into the lake and filter the water. And at Toronto the question of purifying the sewage in some such manner was considered, and very carefully considered at great length, and the decision was reached there to discharge the sewage at one point after the removal of only the heaviest of the sewage mud by settling, the removal of which does not make any difference whatever with the bacterial conditions, and filter the water.

Q. Now, as to the cost of filtering the water supply for the City of Chicago, your estimate was on the theory that the sewage from a population of 1,200,000 discharged into the lake?

A. Yes.

Q. I do not recall the final figures which you gave, but in order that I may get my next question, just state what that estimate was?

A. $13,000,000 for the construction and land.

Q. $10,000,000 for the construction of the plant and an estimated cost of $3,000,000 for enough land on which to operate the plant?

A. Yes, sir, and the operation in addition.

Q. And the expense of operation was in addition to that. Now, if the Drainage Canal had never been built, the sewage from the entire population could have been handled in the same way, could it not?

A. I think it undoubtedly could have been, though it would have involved no doubt, the carrying the sewage some dis-

tance to get proper points of dilution for so large a quantity; and also carrying the waterworks intakes to a considerable distance, preferably in some other direction, to get as far away as possible from the sewage.

Q. I think you said you had made no study of the situation with a view of determining what it would cost to dispose of all the sewage, on the theory that the Drainage Canal was entirely closed?

A. No, sir, I have not attempted that. I started with the assumption that the Drainage Canal was a fixed fact; with 10,000 cubic feet of water that could be diverted through it.

Q. Of course, if they had 10,000 feet of water which could be diverted through the Drainage Canal, that would still take care of a good many more people than are in Chicago now?

A. On the basis of the legal rate, it would take care of 3,000,000 people.

Q. Then it is your judgment that at an outside expense of $13,000,000 it is possible to construct a filtering plant, which would insure the purity of the water supply of Chicago, upon the assumption that the sewage from a population of 1,200,000 people was discharged into the lake?

A. Yes, sir; that is for the present quantity of water. Of course, as I stated, if they draw more water in the future, that it would increase approximately in proportion to the quantity.

Q. That would be something that would be controlled by the growth in population?

A. Exactly.

Q. And with respect to the cost of filtering the water supply, you are quite clear as I understand it, that if you reduce the population from which the sewage goes into the lake, so that you have the sewage of only two or three hundred thousand people to provide for, as is now the situation in the Calumet District, the expense would be less even if you filtered all the water, and it would be very considerably less in case it were found necessary to filter only the water from certain cribs?

A. So far as it might be found unnecessary to filter the water of certain cribs, there would be obviously a corresponding reduction in cost, but if the water were filtered at all, reducing the amount of population providing sewage would not very greatly reduce the cost of filtering. In other words, the filtering that I have in mind for the conditions that I have stated, represents approximately the minimum cost of filtering.

Q. At the risk of perhaps repeating something I have already asked you, would you think the cost would be very materially greater, in case you undertook to filter the water on the theory that you had the sewage from 2,400,000 emptying into the lake, that is, double the 1,200,000 which you had in mind in the preparation of the estimate about which you testified on direct examination?

A. My feeling is in case the sewage canal were obliterated and all the sewage of Chicago were discharged, that the costs involved in taking care of the sewage and water so as to get a good water supply with filtration, would be very greatly increased. I do not think that a large part of the increase would be represented by the increased cost of filtering, but I do think that there would be a very great expense required to take the sewage to appropriate points of discharge far enough off shore to prevent the production of local nuisance, and separated from the waterworks intakes; and to build the longer intakes that would be necessary, and the intakes located away from the sewage outlets; and the land tunnels that would no doubt be necessary in connection with them.

That is to say, of course, I can't say what the scheme would be off-hand, without further study, but in case you threw the canal over and said you would treat the whole sewage of Chicago by dilution in the lake, very likely you would build a big intercepting sewer and take the whole sewage of the city down to some point on the south side and discharge it through a series of outlets going away out into the lake. And you would give up these south waterworks which are near them and perhaps the waterworks up here (indicating) near the mouth of the old Chicago River, which is a dangerous element, as soon as its natural flow is returned to the lake. And you would take the water, perhaps, for the whole city from some point up off Evanston and filter it at that point at one big station, and send it through a great big tunnel going down through the city away to the south side.

Now, I do not say that is what you would do. You might study the thing out and do something very different from that, but whatever it was, you would spend millions and millions of money in solving the problem adequately in that way.

Q. But you have a feeling now that under conditions as they now exist, and in view of the stage which has been reached in your profession, that it would be possible to deal with the sewage situation in the City of Chicago eliminating the Drainage Canal entirely and have good water?

A. It could be done, yes.

Q. Have you made any study of the system that is used in London?

A. The water supply or sewage?

Q. The sewage, disposal of sewage?

A. I have visited the London works, yes.

Q. How do they dispose of it there?

A. It is collected, except storm overflows, in intercepting sewers on either bank of the Thames. On the north bank it is carried down to a place called Barking; on the south side down to a place called Crossness. At those points the sewage is carried through large settling tanks in which the heaviest part of the sewage mud is removed by settling. The sewage is all pumped, I think, before it goes to the settling tanks, and it flows from the settling tanks into the Thames, which, of course, is tidal at this point.

The sludge from the tanks is loaded into steamers, tank steamers, and carried out to sea and dumped. Chemicals have been used at times in the treatment of the sewage so that the process is a chemical precipitation, and directly comparable with that which we mentioned in connection with the World's Fair at Chicago.

Q. Does the problem of the disposing of the sewage in London have anything to do with the water supply, the purity of the water supply?

A. Absolutely nothing.

Q. They are two entirely different problems?

A. Entirely different.

Q. What are the principal cities in which the disposal of the sewage and the water supply become parts of one problem, so that you have to have the disposition of the sewage in mind in dealing with the question of the purity of the water? I am speaking now of the principal cities?

A. The disposal of sewage is a matter of importance to all cities that take their water supplies from rivers receiving sewage above, but there are very few cases where sewage has been purified prior to discharging into such rivers, for the sole or principal object of purifying a water supply taken from the stream below.

Where water supplies are taken from small catchment areas with storage reservoirs as distinguished from large rivers, the problem is somewhat different. There the whole of the run-off, or a large fraction of it, is used for water supply, and the sewage discharging into the water is oftentimes more important relatively.

Boston, New York and many other cities are supplied in

this way. These cities have made efforts to have the sewage from the towns on their catchment areas purified. The towns involved are mostly small. The largest one that I think of is the City of Marlborough, certainly with not over 20,000 people. Boston and New York and some other cities have made persistent efforts to have the sewage from these towns purified, and they have paid the bills in connection with having it done.

There are many other cases where other cities have thought they would like to have it done; they have suggested it; sometimes taken legal means to bring it about, but without offering to pay the bills, and as far as I have heard the purification has not been accomplished in those cases.

In the Great Lakes, the sewage problem and the water supply problem are more intimately associated, in that the sewage and the water supply of the same city may become mixed, and in that respect differs from the river problem, where it is one town above another and the problem of sewage and water is one that almost all the towns on the Great Lakes have.

Q. Milwaukee is one of those?

A. Milwaukee has it, Toronto has it, Cleveland has it; Detroit and Buffalo have it, though in modified form, in much simpler form because there is a definite, strong current in front of them.

Q. Coming back again to the purification of the water of the Calumet before it empties into Lake Michigan, and dealing with that problem on the basis merely of the present population, or double the present population—I understand that is the population which you said you usually dealt with in problems of that kind; that is, you figured on about twice the population of the territory—I would like, if I can get it, as definite an idea as you are able to give us as to the approximate cost of doing that. I am proceeding now on the theory that if you do treat the water, there being the sewage of only two or three hundred thousand people emptying into the river, that perhaps will take care of everything except this 68th street crib, so that that would be the only crib the water from which you would have to filter. Can you give us anything like an exact idea of the expense of handling that situation in that way?

A. You are talking of filtering the water or treating the sewage?

Q. First of treating the sewage?

A. No, sir, I could not tell you about that. If the population of two or three hundred thousand were compactly placed

on the separate systems, it would be comparatively easy to approximate it; but this population is spread over a dozen miles, I should say, and there are various centers of population. There are manufacturing establishments here and there producing waste; and the matter of collecting the sewage and separating it from the storm waters and other flows with which it naturally mixes and which you build purification works for, would very likely cost a good deal more than the cost of the purification itself, and that is something I could not tell you off-hand.

Q. Could you tell what the works themselves would cost for a population of 250,000?

A. Why, I should say that the figures I gave you regarding Paterson were as good an approximation of that as I could give off-hand.

Q. That was about $3,000,000, wasn't it?

A. $3,000,000 exclusive of the cost of separating the surface water.

Q. A part of that, as I recall it, was an expense that could be deferred on account of the population being smaller?

A. Yes, sir.

Q. Now, then, have you given any thought to the cost of a filtering plant merely for the water that comes through the 68th street tunnel?

A. No, sir, I have not.

Q. Assume that one-third of the water supply of the city comes through that 68th street water tunnel, would the cost of building a filtering plant for that water be about one-third of the estimate which you gave for the whole supply? I mean do those figures which you gave run proportionately?

A. Generally they do. I think the real estate for the south one would be a little less in proportion.

Re-direct Examination by Mr. Williams.

Q. When you gave the figure of $500,000 as the annual cost of operating the filtration plant, did that amount include anything for depreciation of the plant?

A. No, sir, that is just the operating expenses, and that is made up of the cost of pumping the water to the filters; the cost of operating the filters themselves, and taking care of the grass, etc., that grows in the top; the cost of the laboratory and supervision and the cost of the final treatment of the effluent with hypochlorite.

Q. What would be a fair percentage of depreciation to figure in those plants?

A. I should say, off-hand, one per cent.

Q. Per year?

A. Yes.

Re-cross Examination by Mr. Wilkerson.

Q. They last a long while?

A. Yes, sir. I do not mean they last a hundred years, but one per cent. marked off for depreciation, I think, will take care of the wear and tear.

Subscribed and sworn to before me this .... day of ...., A. D. 1911.

....

June 1, 1911, 1:30 o'clock p. m.

Parties met pursuant to adjournment.

Present, same as before.

RUDOLPH HERING, a witness called on behalf of the defendant, was first duly sworn and testified as follows:

Direct Examination by Mr. Williams.

Q. Please state your name, place of residence and your occupation?

A. Rudolph Hering. My residence is Montclair, New Jersey; my business office in New York. My occupation is that of hydraulic and sanitary engineer.

Q. How long have you been engaged in the practice of your profession as a hydraulic and sanitary engineer?

A. Substantially since I graduated, 1867.

Q. Will you state in a general way the preliminary education and the experience that you have had in the practice of your profession?

A. I went to Europe and studied my profession at Dresden, Germany. When I came back, after a few engagements not exactly in the line of my present profession—I was then assistant in the construction of the parks of Brooklyn and Philadelphia,—I was engaged by the City of Philadelphia, my

native city, to make investigation on a new water supply for that city.

Q. Before we go on with your experience in the practice of your profession, I wish you would state what societies you are a member of professionally?

A. I am a member of the American Society of Civil Engineers; of the British Institution of Civil Engineers; of the Canadian Society of Civil Engineers; the Western Society in Chicago, and numerous others.

Q. Have you specialized on any particular line of civil and hydraulic engineering?

A. I have specialized since 1873—no, 1875, chiefly in sewerage and water supply engineering.

Q. Do you have any degree from any institution of learning?

A. I have an honorary degree of Doctor of Science of the University of Pennsylvania.

Q. Now will you continue your narration of your experience in a general way, especially with reference to your particular specialty?

A. I was assistant city engineer in Philadelphia, where I had charge chiefly of the sewerage work for some years. Then in 1880 I was commissioned by the United States Government to make a report on the sewerage works of Europe for the National Board of Health. I made that, and it is printed in the annual report of the National Board of Health for 1881.

Then I was engaged by the City of Philadelphia to make an investigation regarding a new water supply. The next engagement was by Mayor Carter H. Harrison in Chicago as chief engineer of the water supply and Drainage Commission, to ascertain what the City of Chicago should do with her sewage, and at the same time guard her water supply against pollution.

After that I was consulting engineer for the City of New York on sewerage work. Then I have been engaged in a number of cities in both water supply and sewerage, Boston, Philadelphia; recommended the present system of water filtration; also Baltimore, the present system of sewerage and sewage disposal; Washington's present sewerage system and also the present water supply filtration, in connection with other engineers; I was a member of a Commission that reported on those matters.

Then Buffalo, Cleveland, Toronto, Indianapolis, Atlanta,

New Orleans; and in all these cases both water supply and sewerage.

Then on the Pacific coast, San Francisco water supply and sewerage; Sacramento water supply and sewerage; Los Angeles sewerage alone; Tacoma, water supply; Victoria, sewerage; Winnipeg, water supply; Ottawa, sewerage.

Now we have the water supply of Montreal, at the present time, purification of the water supply of Montreal; Honolulu, sewerage and Santos sewerage and and water supply.

Q. Who are the other members of the Commission that acted with you in connection with the report which you made and the investigations which you made in connection with the disposal of the sewage in Chicago, and the protection of its water supply, in 1886, did you say that Commission was appointed?

A. Yes, sir. Mr. Benezette Williams and Samuel Artingstall.

Q. Mr. Artingstall was then the city engineer?

A. He was then the city engineer.

Q. As the result of your work, you prepared a report?

A. I did.

Q. And after the report was made, what, if anything, did you have to do with the legislation which was enacted by the General Assembly of Illinois, authorizing the organization of the Sanitary District?

A. I remember being a witness before the legislative committee.

Q. Your only connection with it was from the standpoint of engineering, and at the session of the legislature in 1887 you presented your veiws to the legislative committee?

A. I did.

Q. From that time to this have you in a general way kept informed as to the conditions in Chicago, lake conditions and conditions as to water supply and sewage disposal?

A. I have tried to keep myself informed in a general way. Having lived there, I had friends, and would stop over, and perhaps on other works, consultation and so on; and as one of my former assistants in Chicago was City Engineer, Mr. Erickson, I kept posted on his work very nicely. I also know Mr. Cooley very well, and also Mr. Williams, Benezette Williams, and in that way kept posted on the progress of the Drainage Canal. I went to see it during the construction; took a lot of European engineers over it during the World's Fair time, while it was under construction.

Q. During recent years, have you made any particular study of the situation as it has developed since the construction of the channel?

A. In 1906 I was engaged with my associate, Mr. George W. Fuller, by the International Waterways Commission to make a certain examination and report.

Q. That report you made and it was published?

A. That report was submitted on December 18, 1906, and was published as an appendix to the report of the International Waterways Commission, dated Toronto, Ontario, January 4, 1907.

Mr. Wilkerson: That is Appendix F?

A. That is Appendix F. Appendix A was the report that I made in January, 1887.

Mr. Williams: Q. Subsequent to the report that you and Mr. Fuller made to the International Waterways Commission, did you make any further detailed study of the situation with respect to the Calumet District and the Sanitary District, and make any report?

A. I did. At the request of Honorable Robert R. McCormick, president of the Sanitary District of Chicago, in the latter part of 1907, I made such a report, entitled: "Report on the Disposal of Sewage from the Calumet Subdivision of the Sanitary District of Chicago," dated October 15, 1907.

Q. Will you state in your own way, Mr. Hering, what different methods there are now successfully employed in the disposal of sewage, in a general way?

A. The most common method for large cities is a system by dilution, which means that the sewage is discharged into flowing water in a way to be thoroughly dispersed in it, and in such quantities that the oxygen dissolved in the running water is sufficient to oxidize the sewage matter.

The second way is to purify the sewage on land, according to several methods, depending upon the availability of land areas and certain kinds of land suitable for natural filtration, and upon other local conditions.

Q. Do climatic conditions enter into the consideration in any way?

A. They do. You can vary the system somewhat when you get into warm climates, generally in the way of economy. When you get into northern climates, you sometimes have to increase their cost by making your works perhaps larger or by preventing an injury to the works, relative injury to the works due to extreme cold weather.

Q. Taking into consideration, Mr. Hering, the fact that the Sanitary District has already constructed its main channel and has entered upon a plan of sewage disposal for the Sanitary District by the dilution method exclusively; and assuming that there is a capacity through that main channel to provide for the disposal of sewage by that method for a population of 3,000,000 people; and assuming that there is a large area on the south known as the Calumet District, a portion of which drains into the Calumet River which flows into Lake Michigan, a part of that area being sparsely settled; and taking into consideration the probable growth in population during the coming years, and the probable necessity to care for a population eventually of at least 4,120,000 in the entire sanitary district, what method of sewage disposal would you consider the most efficient and economical to carry on, for the added territory, and to provide for the added population at this time?

Mr. Wilkerson: Let this go in subject to the same objection that was made to the same line of testimony on the part of the witness Mr. Hazen on yesterday, without stopping to repeat the objection, either specifically with respect to this question or as to any other question; it may all be treated as going in subject to the same objection.

Mr. Williams: That is all right.

The Witness: It is my opinion that the proposed canal called, I believe, the Calumet Sag Canal, offers the most economical, and as I believe the most preferable method of disposing of the sewage of that part of Chicago.

Q. You prepared figures, did you, as to the cost of installing other systems for the disposal of sewage for the Calumet territory?

A. I did.

Q. In the original plans that were suggested by you and your associates upon the Commission that was appointed by Mayor Harrison, was it contemplated at that time that the method now proposed should be carried out eventually?

A. It was contemplated; the matter was then seriously discussed, but our commission thought that it was a little bit distant to bring into the report at that time as regards details, because the money that we had was short anyway to complete the work that we had in contemplation for the built-up section of the city. And as you may know, the report that was issued was entitled a preliminary report with the expectation that we would make a final report. That was never made on account

of inability to get any further appropriation. His Honor, the Mayor, and his Council, stated that that preliminary report was entirely sufficient for them, and that they could proceed.

Q. In your investigation of the situation in the Calumet region and in the Sanitary District in general, did you have a report of the population and the growth of the population during the past numbers of years?

A. I did.

Q. The population curve, indicating the probable growth of the population?

A. I had prepared such data.

Q. From your investigation, aside from the dilution method what was the most economical method of disposing of the sewage of the Calumet district that you were of opinion was practical?

A. It was the method of purifying sewage on land to a degree which would make the effluent water non-putrescent. That method which we found to be the cheapest was one that we call the springling method, sprinkling filters, where the fluids, the liquids are sprinkled over beds of stone, coarse broken stone, and thus allowed to oxidize, and the solid matter which is previously settled out of the sewage is treated by itself, of course, in another way so that it would gradually rot out and constitute inoffensive solid material that can be used for filling or any other purpose for which material is used.

Q. How large an area of land would be necessary to dispose of the sewage by that method for a population of say 1,200,000 people.

A. It would require about 80 acres of sprinkling filters, and an additional area for tanks, and basins for sludge treatment, and for other purposes.

Q. Is any particular soil required for that kind of a plant?

A. No; no, it is entirely independent of the soil. The purification of the liquid is accomplished by oxidization in artificially prepared filters.

Q. You prepared an estimate of the cost of such a plant on the basis of a population of 300,000, which was regarded as being rather imminent, and an ultimate population of 1,200,000?

A. I did.

Q. Will you state the estimate of cost for both populations?

A. The estimate of cost for a population of 300,000 was

$4,761,000. The estimated cost of works for a population of 1,200,000 was $9,257,500. The annual cost of operation, and including interest on the investment, depreciation of machinery and so on for a population of 300,000 was $360,240, and for a population of 1,200,000 was $900,300.

Q. Did you separate, or have you the figures separate as to the annual cost of operation from the fixed charges of interest and depreciation?

A. I have.

Q. What was the annual cost of operation exclusive of the fixed charges?

A. For 300,000 population it is $139,000, and for a population of 1,200,000, $423,000.

Q. And at what rate per cent would you capitalize those annual expenses, in order to obtain a fund to perpetually maintain the plant?

A. I did not capitalize the annual cost, but I took an interest of 4 per cent. as the interest on the invested money, believing as we do, that a comparison between the cost of works is more in accordance with the actual condition if we compare the annual costs rather than the capitalized costs, which are more or less imaginary. I mean they are merely book figures; they are not real. They do not have to be expended.

Q. Since that report was made, have you given any further consideration as to the adequacy of the works that you have outlined in that report and of the figures that you have given to cover the cost of performing the work that you intended, expected would be performed by the works that you described in your report?

A. There has naturally been some progress made since then; and if I were to estimate the cost again today, I would increase it somewhat.

Q. For what reason and to what extent?

A. I would increase it because we are now able to treat the sludge in a manner so that there is no odor when it leaves the works, and for this additional advantage, I believe it is proper to pay an additional cost.

Q. Have you estimated any additional works in the way of treatment of the effluent?

A. I would also do that, which was not included in this estimate; that is a treatment with hypochlorate of lime so that the pathogenic bacteria that may escape from this rapid method of filtration would be destroyed, in the same way that we

now protect our water supplies, probably in much over a hundred cities in this country.

Q. In your opinion, in case the sewage of the Calumet district were disposed of by the sprinkler system and the effluent discharged into the Calumet River and from thence into the lake would it be reasonably necessary to treat that effluent with the method you described?

A. I should advise it today, because it is a fairly economical method and gives an assurance of protection against those diseases which are likely to be propagated by sewage bacteria.

Q. Have you made an estimate of what added cost would be involved in such treatment above the cost that was considered by you in making your report?

A. I have not; but I have reported such a method to the City of Oswego on the lakes; and also have been making some other studies for such treatment on the lakes; and I have made a general estimate.

Q. Will you give us a general estimate which in your opinion, as near as you reasonably can, would indicate the additional cost that would be involved in the installation of such a process?

A. The cost would depend mainly on the amount of very fine suspended matter that is still left in the effluent sewage. This treatment attacks the organic matter in the sewage, and in order to be sure that it is also destructive of the pathogenic bacteria, we assume that it must be rather severe in order to prevent such bacteria from escaping together with the organic matter in suspension.

We therefore allow a much smaller amount for water that is clear, such as would be used for water supply than we do for water that is an effluent sewage, with fine suspended matter still remaining.

I have made, therefore, two figures, and would say that in the Chicago case it would depend upon the carefulness and thoroughness of the treatment as to which of these figures, or what figure between, would be proper. I will say that it would require per million gallons of sewage between 75 and 150 pounds of hypochlorite powder, which is the main expense.

Q. Is that sewage raw sewage or effluent?

A. That is effluent sewage, and treated merely by sedimentation, not filtration, or a high degree of purification. Of course, there is some labor required, so that I would say the

cost per million gallons of sewage would range from $1.25 to $2.50 in round numbers.

There is no allowance made in that for interest or depreciation in the works; nor for high grade intelligence such as chemists, which in a large city would be fairly small per million gallons.

Q. Do you know the average rate per capita per day of sewage that is calculated to be produced by people like Chicago people?

A. The quantity of sewage is usually estimated the same as the water supply, which I understand is 230 gallons per capita per day.

Q. Assuming, Mr. Hering, that works such as you have described briefly and referred to in your report, sprinkling filters, were installed, and the sewage of the Calumet district is cared for by that system, and the effluent treated as you have indicated it should be treated, would there be any difference in the cost of operation of such a plant in the winter months from the cost during the summer months?

A. There would. The activity of the bacteria in purifying sewage is much less in winter than in summer, and you would either get a less degree of purification or you would have to increase your plant correspondingly to get the same purification as in summer. And then it requires watchfulness. The sprinkling beds if not covered by a roof will have snow and ice upon them, and it is certainly not as simple to keep the filters at work. It would require possibly a larger number of men to keep the nozzles free and have things working right than in summer.

Q. Do you recall whether or not those considerations entered into the estimates that you made at that time?

A. I can't remember that we made—certainly we did not make a material allowance for winter conditions, with the thought, as I remember, that as time went along there might be some way of increasing the efficiency, although none was known to me at the time. But I did not care to load the estimates with something that I was not entirely sure of, particularly as it appeared that the sprinkling filter project was the more expensive one.

Q. Now, assuming that we have in operation the sprinkling filter system and a population of either 300,000 or 1,200,000 in the Calumet district; and the effluent is treated in the manner that you suggest; and that the system works satisfactorily, as well as such a system can be expected to work; the effluent is

discharged into the lake and treated in the manner that you have suggested, carefully and as efficiently as it can be, what is your opinion as to whether or not that method would be as satisfactory in disposing of the sewage of that territory as it would to divert it by means of sewers into a channel, the Calumet Sag Channel, and thence into the main channel of the Sanitary District and down the Illinois River, so that no part of it entered the lake?

A. As an engineer, I should certainly prefer the dilution method; and I think I should also as a citizen, because it is more simple. You do not depend on a number of factors that have to work together.

Q. There are human agencies you must depend upon, and mechanical contrivances and climatic conditions in connection with the sprinkler system, which would not affect the dilution method?

A. Yes. While I would not in the least be afraid that the sprinkling system would not give satisfaction, if I had the choice I certainly would try to get the results in a more simple way.

Q. The rate of dilution provided for by the present law of the State of Illinois is 20,000 cubic feet of water for each 100,000 of population, per minute. Assuming that there are no auxiliary works to treat the sewage before it enters into the canals and is subjected to the dilution process, what do you say as to the reasonableness of that proportion of dilution assuming no—

A. May I ask you what you mean by no auxiliary works?

Q. Namely that the sewage goes in in a raw state, without any treatment before it goes in, not any of the coarse stone treatment, no sedimentation, no tanks; it just goes in as it goes in now. Assuming it goes in as it goes now, what do you say as to that rate of dilution?

A. I am always on record, and I would like to be so now; and I believe in coarse screening under all circumstances.

Q. Assuming that there is not even that?

A. Then so far as a nuisance is concerned, other than to see large floating matter parading down the river, I would say this dilution was entirely satisfactory.

Q. Do you think that any less proportion would be sufficient, assuming that there were no screens and no auxiliary—

A. I think that dilution ratio that we stated in our report is the least that will give satisfaction.

Q. Assuming that the population of Chicago, the sanitary

district rather, should reach a figure whereby it would be impossible to comply with the provisions of the state law respecting the amount of water to be diverted from Lake Michigan, in proportion to the population, without exceeding the 14,000 cubic feet of water per second which we are contending for in this suit, has the science advanced any in recent months so that you are able to give us an opinion as to any auxiliary works that can at that time be established to increase the efficiency of the dilution method, and render it possible to decrease the proportion of water that may be necessary to accomplish the same results as are now accomplished by the entering of raw sewage into the channel?

A. There has recently, that is within the last few years, been developed in Germany a method of treating sewage where as in all other cases of land treatment it is endeavored to separate the liquid from the solid matter, which allows us now after separating the solid matter from the sewage, to allow it to decompose under water and with certain restrictions, in such a way that anywhere from three to six months after, according to climate, temperature, character of sewage, the solid matter may be taken out and then have no odor, so that a nuisance at the works is not created.

This makes it possible to have the separation accomplished in the midst of habitation, without offense, and the sludge removed without offense. This discovery makes it possible hereafter to remove from the sewage that portion which causes the greatest amount of nuisance, and thereby allow the liquid to be discharged into water with much less dilution than the legal rate, controlling the work of the Sanitary District. And therefore a possibility exists of increasing the amount of population correspondingly that may discharge into a river, without offense.

Q. If this method were employed throughout the entire Sanitary District, and the present impressions as to the success of this system are borne out, to what figure could you reduce the dilution?

A. I would say by a quarter to a third.

Q. What expense would be involved in the installation of such a system?

A. I have not figured out that expense, but I would say that experience in Germany, as applied to our American conditions, would indicate that the construction of these tanks would cost about $1.50 per capita.

Q. And there would be some cost of operation?

A. Then there would be some cost of operation, which would consist of pumping out the sludge into barges and carrying it away to a point of disposal, which of course I can't estimate, not knowing where it would go.

Q. Mr. Hering, if the problem of the disposal of the sewage of Chicago and its environs were now presented to you for the first time instead of in 1886, in the light of your experience since that time, would you make any different or other report with respect to the method of disposing of the sewage than you made at that time?

A. I would still recommend the dilution method.

Cross-Examination by Mr. Wilkerson.

Q. These three reports to which you have referred, Mr. Hering, are the ones designated as Appendix A to the report upon the Chicago Drainage Canal by the International Waterways Commission and Appendix F to the same report; the same appearing in the government print under date of 1907, and the report which you made to Mr. McCormick, the President of the Sanitary District, are they not?

A. Yes, sir.

Q. Those are the three reports?

A. Yes, sir.

Q. The one to Mr. McCormick is dated Chicago, October 15, 1907?

A. Yes, sir.

Mr. Wilkerson: I should like to have those reports identified, and I now reserve the right to read at the hearing in connection with the examination of the witness either those reports in full, or any part of the reports. What I want to do is to get the record in the same shape as if in connection with the cross-examination of the witness I had him identify each one of these reports, and had had the reports copied at length here, for the purpose of identification as his report.

Mr. Williams: For the purpose of identification?

Mr. Wilkerson: And I reserve the right in connection with his examination to read any part of the report in connection with his testimony that I see fit. The point is this: that when the deposition of this witness is read, I may read, if I see fit, in connection with his testimony, any statements in these reports, without putting questions to him right now and asking him whether he said this or that. It is to save time, that is all.

Mr. Williams: All right.

Mr. Wilkerson: Of course I shall contend that any statement which he made in any one of these reports is legitimate cross-examination; that is the statement should be read as cross-examination.

Mr. Williams: If you want to controvert any statement he makes in his reports—if you want to introduce the reports in evidence in your proof afterwards, in order to dispute something he said today, you can do that; or if you want to call his attention to any particular thing he said today, when he said something to the contrary before, and ask him to explain it, that would be all right.

Mr. Wilkerson: I am making no contention of that kind. He has testified on the general subject, concerning which he made prior statements. I could sit down and read these statements, and that would be proper cross-examination.

Mr. Williams: There are two ways by which you can take up any statement today that may seem to you inconsistent in any of these reports; the first is to call his attention to the fact he said so and so before and, what is your explanation of the inconsistency, if there be any. Or if you do not want to say that, you come in and say having said this before—

Mr. Wilkerson: I hardly think I am limited to that, Mr. Williams. All I want to do is to shorten the record.

Q. The first report, Mr. Hering, to which you referred in your direct examination is the first report which is designated Appendix A?

A. Yes, sir.

Q. It is under date of "Chicago, January, 1887". It is signed "Rudolph Hering, Chief Engineer, Benezette Williams and Samuel G. Artingstall, consulting engineers."

A. Yes, sir.

Q. I will ask you to look at the document which I hand you and state whether that is the report (handing witness document).

A. This is the report.

Q. I will ask you to read it.

Mr. Williams: I will object; it is improper cross-examination, and it is not a question put to the witness, but a direction to the witness, and the witness is under no obligation to read anything. If counsel wants to read anything or have anything read, he can do it himself *voire dire.* I object to having it shown that he is reading it into the record. I haven't any objection to his reading it for his own informa-

tion, in order that he may understand any questions you are going to ask him.

Mr. Wilkerson: I ask the witness to read the report and Mr. Williams objects to it.

Mr. Williams: Read the report into the record?

Mr. Wilkerson: Yes.

Mr. Williams: And I object to it, on the ground, first, that the instruction to the witness to read a document is improper, and is not in the line of cross-examination; that the direction is not an interrogatory intended to elicit any fact bearing upon the direct testimony that has been given; and that the witness is under no obligation to comply with any direction of counsel to read documents into the record, when such documents have not been introduced and have not even been offered in evidence; and counsel is not in a position at this time to offer testimony in his own behalf.

Mr. Wilkerson: Now, I say, with respect to that that the witness on direct examination has testified as to the making of a certain report. He has testified that at the time the report was made, he had in mind certain other things.

The report is called to his attention as the foundation for a line of cross-examination, and in order that the cross-examination may be intelligible, it is essential that the report to which he has referred and upon which the cross-examination appears may be in the record. As to whether the report itself is to be treated as a part of the cross-examination of this witness, to the extent that it becomes a part of the defendant's case, I am perfectly willing to let that question be reserved for the ruling of the court at the trial.

I think that on neither side will there be any particular difficulty if this report appears as having been read by the witness into the record as the basis for this cross-examination; the counsel for the defendant reserving his right that it shall not be treated as a part of his case; and leaving it for the Judge to decide whether the report is a part of the estimony for the defense.

Mr. Williams: I am perfectly willing that the witness be permitted to examine the report, read it fully; and that counsel may read it for his own information fully.

I object to the witness reading into the record any document or paper not offered in evidence. So far as identifying the document is concerned, there is not the slightest difficulty. It may be marked as an exhibit for identification and attached to the deposition, so that it may be hereafter offered

in evidence and made a part of the record, but I shall object to, and ask the witness to refuse to read into the record a document which has not been introduced in evidence in the case.

Mr. Wilkerson: In order that the witness may not be embarrassed by the comflicting directions of counsel, and in the absence of the court, I will direct your attention, Mr. Herring, to this report, Appendix A, which is as follows:

"Chicago, January, 1887.

To the Honorable Mayor and City Council of the City of Chicago:

Gentlemen: On January 27, 1886, your honorable body passed a resolution authorizing the creation of a drainage water-supply commision. After being amended, February 23, it read as follows:

Whereas pure water and scientific drainage are necessities of this community, and the people demand a system of water supply and drainage adequate to meet the requirements not only of the present, but of years to come, nor will any temporary expedient or makeshift satisfy them; and

Whereas a thorough and permanent system of supplying pure water to our citizens and caring for the drainage of the municipality can not be paid for out of current taxation, therefor it is desired that a plan shall be devised and perfected before the next meeting of the legislature to the end that necessary legislation may be had.

For the purpose of carrying into effect the objects sought, there is recommended the appointment by the Mayor of a commission to consist of one expert engineer, whose reputation is so high that his opinion and report will command the respect of the community, and with him one or two consulting engineers of like experience in engineering and sanitary matters. The duty of this drainage and water supply commission, made up as above set forth, should be to consider all plans relating to drainage and water supply which may be brought to its attention; to make such examinations and investigations and surveys as may be deemed necessary; to collect all information bearing on this problem; to consider all recent developments in the matter of sewage disposal, and their application to our present and future needs; to consider and meet necessity of increasing our water supply and of

protecting the same from contamination; to remedy our present inadequate methods of drainage and sewage disposal; to consider the relations of any system proposed to adjacent districts, and whether there may not be a union between the city and its suburbs to solve the great problem; to determine the great question as to the interest which the State and the United States may have in the disposal of sewage by way of the Illinois River, and to devise plans to meet any objections thereto, if such a system shall be thought best; and in general to consider and report upon any and all things which relate to the matter of water supply and drainage of the City of Chicago.

The commission should report on the whole matter committed to it in the most full and comprehensive manner, with maps, plans, and diagrams complete, and accompany the report with estimates of the first cost and annual requirements for the maintenance of the system proposed.

The report of the commission should be made as early as practicable, and not later than the convening of the next session of the Illinois legislature, in January, 1887.

In consideration of the foregoing, be it,

Resolved, That the Mayor be, and is hereby, authorized and directed to employ on behalf of the city one expert engineer of reputation and experience in engineering and sanitary matters, at a salary not to exceed $10,000 per annum, and also to employ such consulting engineers, not exceeding two in number, as may seem necessary, and such assistant engineers as may be required, all to be paid according to services rendered, for the purpose of carrying out the objects set forth in the preamble hereto. For the fees of said assistant engineers and for all expenses connected with said work there shall be allowed not to exceed the sum of $20,000. All fees, salaries, and expenses connected with said work shall not exceed in the aggregate the sum of $30,000, and the same shall be paid from the water fund of the city upon vouchers audited by the Mayor and city comptroller.

In accordance with the terms expressed herein his honor, Carter H. Harrison appointed Rudolph Hering as chief engineer, Benezette Williams and S. G. Artingstall as consulting engineers, who together should constitute a commission. Mr. Hering entered upon duty March 28,

Mr. Williams September 17, and Mr. Artingstall December 21, 1886.

The investigation designated by the resolution was a formidable one, composing no less a task than the consideration of the entire subject of the future water supply and drainage of Chicago. It appeared doubtful from the beginning that a report such as was demanded could be furnished within the specified time, for the simple reason, if for no other, that observations of the lake phenomena and of the flow of certain rivers should be extended over at least one year, covering four consecutive seasons, in order to draw satisfactory deductions.

But the large amount of work alone that was asked for made it impracticable to present a complete report in so short a time. It was expected, however, that results could be reached sufficient to indicate the character of legislation required to carry out any project that might be determined upon, and that therefore a preliminary report having this end in view could be made at the stated time, leaving to a later date the presentation of a report outlining the detailed features of the scheme recommended and embracing the minor results of the entire inquiry.

The present communication is to cover the ground indicated for the preliminary report, and besides containing the conclusions reached regarding the main features of the proposed project, it contains also a brief review of the work done during the past year and of what still remains to be done.

The month of April was devoted to a general examination of the subject of the territory to be investigated, and of the various suggestions that had been made toward effecting a solution of the problem.

The examination disclosed the fact that the city is sometimes greatly suffering from the offensive condition of parts of the Chicago River and its branches, caused by the discharge of sewage into the same, and from the occasional contamination of its water supply, brought about by the discharge of the polluted contents of the river into the lake. It also disclosed the fact that almost every conceivable way of dealing with these questions had been suggested and in some forms applied during the past thirty years.

The problem therefore demands the attainment of two ends—the protection of the water supply and the removal

of the river nuisance. As the water must be taken from the lake, it is evident that both its pollution and the objectionable condition of the rivers should be prevented by a better disposition of the sewage. It is, therefore, the latter question which constitutes the main object of this investigation.

Among the possible methods of getting rid of the Chicago sewage there are but three that have been deemed worthy of an extended consideration, namely: A discharge into Lake Michigan, a disposal upon land, and a discharge into the Des Plaines River. The preliminary work, has, therefore, been confined to these three projects, and was classed as topographic, hydrographic, and miscellaneous.

At the time when the present commission began its labors the topographical work had already received some attention. Surveys were being made of the Des Plaines River from Bridgeport westward under the direction of Mr. Artingstall, city engineer. These surveys were continued, and have now been completed as far as Joliet. They include contours of the entire valley and borings to rock between Bridgeport and Lemont. In order to understand the hydrography of the Des Plaines Valley above the point where the Chicago sewage could be discharged into it, and also to ascertain the probable magnitude and effect of floods in the river, a survey was made of its bed as far north as Northfield township. To determine the area of the basin its entire divide was located. To ascertain the practicability of diverting the flood waters from the upper portion of the Des Plaines and North Branch water sheds directly into the lake, and thus avoiding the difficulties which would arise from their passing through the Chicago River, all feasible lines were surveyed. Finally, a few levels were taken of the area adjoining the city wherever no connected levels existed to show the general topographical features of the territory over which the future city will spread out and from which the drainage will require artificial removal.

The hydrographic work consisted in ascertaining the flow of the Des Plaines River, the rainfall upon its area, its flood discharges, the character of its bed, and the probable effect of discharging the Chicago sewage into it when diluted by a large and constant stream of water from the lake. It consisted, further, in examining the

nature of the currents in the lake and in studying the rise and fall of its level, and in ascertaining the amount and character both of the sewage discharged into it and of the deposits in the river and lake in front of the city to determine the effects of the present sewage disposal.

Inquiry and surveys were made to show the feasibility of purifying the Chicago sewage by filtration on land. Land damages were carefully estimated for the different schemes; existing records were searched concerning borings and excavations made in and about the city, so that the practicability of certain lines of tunnels could be discovered; the probable growth of the city and its suburbs, as well as the probable distribution of the future population, received a careful attention, and, finally, a large number of data were compiled which pertain to the existing works of water supply and sewerage in Chicago and the adjoining towns.

In reporting the result thus far gained we will present them in the order most convenient for discussion, but before doing so will briefly describe the present manner and effect of the sewage disposal, as shown by this investigation.

Present Sewage Disposal.

The sewage works of Chicago and suburbs have been planned on what is called the combined system, in which the sewers serve for the removal both of sewage and rain water. In the town of Evanston they empty into the lake. In the town of Lake View they partly discharge into the lake and partly into the North Branch. From the north and west divisions and part of the south division of Chicago, the drainage enters the Chicago River and its branches, and from the remaining part of the south division it flows into the lake at three outlets, situated respectively, at Twelfth, Twenty-second, and Thirty-fifth streets. The sewers of Hyde Park discharge into the lake excepting those of Pullman, where the sewage is disposed of on land. The town of Lake, including the Stock Yards district, drains into the South Fork of the Chicago River.

When the sewage works of this city were designed, in 1856, by Mr. E. S. Chesbrough, it was apprehended that ultimately some means would have to be found to change the water in the river from time to time or to keep the

sewage entirely out of it. The first step toward improving the condition of the river was taken by deepening the Illinois and Michigan Canal, so as to cause a current from the lake to the Des Plaines River at Lockport. The next step was the building of the Fullerton avenue conduit in order to produce a circulation in the North Branch; and the last step was the erection of the canal pumping works to increase the flow in the river, which had become greatly polluted.

The influence of these works is confined to the main river and its north and south branches. But the south fork of the latter, receiving a large amount of sewage from Chicago and the town of Lake, and charged with the waste from the Union Stock Yards and packing houses, has no artificial means for a circulation of its water, and as a consequence is in a condition of great filthiness.

The accompanying diagram (a) has been prepared to show the present pollution of the Chicago River and its branches during the time when all of their water is discharged into the canal by the Bridgeport pumps. On the left are shown the main river and the north branch, one above the other, their combined waters forming the south branch, and reaching Bridgeport on the right, where they are lifted into the canal.

At the latter point the south fork is shown as joining it. The shaded portions indicate the amount of sewage entering and passing the respective points, and the blank portions the lake water diluting it. The degree of dilution is shown by the relative areas. It diminishes in the north branch from Fullerton avenue to the south branch, and becomes still less toward Bridgeport, and finally receives the foul waters of the south fork.

The depth and character of sewage deposits in the river and harbor, as might be expected, vary considerably. They are not great in the track of the vessels, but increase toward the docks and quieter portions of the slips, where they reach a depth of from one to four feet. While the deposits in the channel are of a heavier kind, such as cinders, those in the docks are mostly a foul mass of decomposing organic matter. No form of life is found to exist above Clark street bridge as far north as Clybourn

(a) Omitted; printed in House Ex. Doc. No. 264, 51st Cong., 1st sess.

place and as far south as Ashland avenue. The effect of this condition of the river is to endanger the purity of the water supply whenever the river, with its accumulated deposits, flows into the lake, which occurs when the rain water that finds its way into the river exceeds the amount pumped into the canal. If this excess is great, as in the spring and occasionally in the summer months, the contamination of the lake is considerable, and must constantly increase.

From the foregoing it is seen that the present method of disposal of the sewage from Chicago and its suburbs is partly by discharging it into Lake Michigan, but mainly, except during floods, by discharging it into the Des Plaines River.

Future Population.

The first question which requires an answer, and upon which many of the subsequent inquiries depended, was the population which it is economical and advisable to consider at present, and the extent of territory upon which such a population will be located.

The growth of Chicago has been frequently quoted as phenomenal. Estimates made thereof for various purposes have turned out to be rather under than over the actual result.

It is taken for granted that Chicago and its suburban towns will have to dispose of their sewage so that the water supply for the entire community residing near the lake from the south line of Hyde Park to the north line of Evanston will be guarded against pollution by the sewage from any one of its separate communities. For this purpose the whole populated area within the above limits is considered as forming one city with a common interest.

The growth of this metropolis was obtained partly from the United States census and partly from the school census of Cook County, which gave a record up to the summer of 1886. In order to forecast the probably ratio of the future increase it was desirable to compare this growth with that of other cities. By considering the natural ratio in increase elsewhere, and including the natural suburbs of each city, a fair and instructive basis of com-

parison was obtained; and by realizing the respective natural advantages for growth in each of the communities the probable ratio for Chicago was determined with a satisfactory degree of exactness.

The accompanying diagram shows the results of this comparison. It represents by curves the population of the largest cities in the country since 1790, not as usually quoted from the census, giving the inhabitants on certain arbitrary areas fixed by law, but as virtually making up the population of the respective municipalities, by including adjacent towns and natural suburbs, the only method which enables the true growth of the great cities to be recognized. For instance, the New York center naturally includes Brooklyn, Jersey City, Hoboken, Newark and other suburbs, and Chicago the entire territory from Hyde Park to Evanston.

The diagram indicates that the character of growth of the different cities permits them to be divided into two distinct classes. Philadelphia, Boston, St. Louis and Cincinnati show very much the same character of increase, and represent by comparison the more conservative communities. New York and Chicago, on the other hand, while showing a remarkable resemblance to each other, form quite a contrast to the rest of the cities, and might be called the more progressive communities. The diagram finally indicates the time when the Chicago curve, which was the lowest one prior to 1864, intersected in turn those of St. Louis, Cincinnati, Boston, and there is a high degree of probability of its intersecting the Philadelphia curve in or before 1891—*i. e.,* in four years from now—after which Chicago will be the second largest center of population in America.

As it is not practicable in so young a city as Chicago to forecast a definite line of growth, it is preferred to give the probable maximum and the probable minimum between which the true line will most likely be contained. The minimum line represents a growth resembling that of New York and the maximum line assumes the ratio of increase per decade to be consistent instead of gradually decreasing as in most other cities. The result indicates that the population of Chicago and suburbs will be 2,500,000 between the years 1905 and 1915, or about three times the present population in 18 to 28 years.

In providing public works for large communities it

must be borne in mind that it is economical to invest only such sums as will bring a return within a certain number of years, leaving expenditures for benefits that will be realized only at a later time to a later generation. This fact, together with the probable growth of Chicago, shows it to be economical and judicious at present to plan works sufficiently extensive to dispose of the sewage of not less than 2,500,000 inhabitants.

In addition to the population the area that will be occupied by it has to be determined. While this is a far more difficult task, owing to the many accidental causes influencing the distribution of the population, it is possible nevertheless to outline the area sufficiently close for the present purposes.

The future metropolis, with a population three times as great, will be distributed along the lake from South Chicago to Evanston, and will reach inland to the Blue Island Ridge on the south to the Des Plaines River in the center, and to the higher parts of Niles Township in the north. Outside of these general limits, a more or less dense population will extend for some distance along the lines of railroad.*

As inferred above, it is proper to consider at this time the wants of the population that will reside upon this entire territory.

Discharge of the Sewage into Lake Michigan.

To discharge the sewage from cities into comparatively large bodies of water is not only the usual, but often the best method for its disposal. Dilution and dispersion thoroughly expose it to the action of the oxygen contained in both the water and the superincumbent air; it is thereby gradually oxidized. Where the body of water is a large river with a strong current, the best conditions for such purification are found. Where it is a lake in which the circulation is slight and irregular, the efficacy of the method is less and depends for its success on the character of the currents and the relative amount of sewage to be discharged into it.

The hydrographic surveys of the lake made during the past season were therefore partly for the purpose of

*Here occurs a diagram showing the "growth of several population centers in the United States," not here reproduced.

ascertaining, if possible, the laws governing the currents, so that we would know their effect in dispersing the sewage discharged into the lake. The trend of the shore currents was actually ascertained by daily recording the direction of spar buoys placed at the Chicago waterworks crib, at Michigan City and at St. Joseph. A large number of bottle floats were thrown into the lake at different points and different times for the same purpose. They were partly single surface floats and partly double, the lower one being placed at varying depths, according to the depth of the water. More than half of them have been picked up and returned, with place and date noted. The currents were also observed by means of large can buoys from an anchored tugboat at different points in the lake, extending from Hyde Park to Evanston, about six miles from the shore. Two general lake trips were undertaken, one to St. Joseph and Back to Grosse Point, and another one parallel with the shore around the head of the lake.

When the observations are completed and compiled in detail, some valuable information will be available for the question of water supply. Light will be thrown on the movement of the water under different winds and the sudden changes of temperature of the water at the crib and on the turbidness of the same.

The following results have a bearing on the question of sewage disposal: Where not affected by local conditions, the currents practically go with the winds in water of moderate depth and quickly respond to any change. In deep water also the surface currents run with the wind, but at the bottom and even at mid-depth the direction is usually different. The prevailing current along the shore of Cook County during the past summer has been observed to be toward the north, but it is possible that this result may be different during the winter months. In the open lake wave action seems to be effective in preventing the permanent deposits down to a depth of about 60 feet; inside of the breakwater sewage deposits are found on the bottom.

The general deduction from these results is clear that, as no constant current exists which would carry the sewage away in one direction, it should be discharged into the lake at one end of the future city, while the water supply should be obtained as far away from it as prac-

ticable towards the other end, a conclusion which is being acted upon in the other large lake cities. The proper place from which to bring the water would be opposite Grosse Point, and the sewage discharge should be east of Hyde Park. While it might be practicable to allow the sewage in its crude form to enter the lake under such conditions for many years, the necessity would arise later for clarifying it at least partially previous to its discharge. It could not be allowed to run into the river as at present, but the dry weather flow and a considerable amount of storm water would have to be intercepted and carried to the outfall through many miles of special conduits. This entire quantity would have to be raised by pumping in order to get sufficient head to empty into the lake, while the diluted sewage during storms, in excess of the capacity of the intercepting sewers, would be allowed to discharge directly into the river.

The water supply would have to be brought from Grosse Point in large conduits to the several pumping stations scattered over the city and its present suburbs. The circulation of the water in the Chicago River and branches would have to be maintained practically as it is at present, because the removal merely of the dry weather flow of sewage would not altogether prevent its pollution.

Disposal of Land.

We shall not at this time enter into a general discussion of the principles underlying land purification of sewage, or make historical references showing the success or ill success of the method as practiced elsewhere. We will simply state that with good management under ordinarily favorable conditions a disposal on land proves satisfactory, so far as the purification of the sewage is concerned, and that with proper conditions in the way of good markets and a favorable soil and climate sewage farms can be operated on a large scale after the sewage is delivered upon the same without financial loss.

In speaking of a sewage farm of the magnitude required for the metropolitan area of Chicago, it is not understood as being land devoted primarily to the raising of crops, using the sewage only when and where it would most promote the growth of vegetation. The primary

object would be the purification of the sewage on an area of land as small as could serve the purpose. Technically speaking, the sewage disposal would be by means of intermittent filtration rather than irrigation. To carry out such a scheme for Chicago involves the following:

(1) The acquirement of sufficient land suitable for the purpose.

(2) A comprehensive system of intercepting and collecting sewers carrying the sewage to the farm.

(3) Pumping works of a capacity to handle all the dry weather flow of sewage and a certain proportion of storm water.

(4) A thorough underdrainage, leveling and preparing of beds for the filtration areas.

(5) A system of underground conduits and surface carriers for distributing the sewage over the ground and a system of open ditches for removing the purified water to the nearest water courses.

(6) Buildings, roads, and a complete farming outfit.

(7) An organization for properly distributing the sewage, for carrying on the farming operations, for conducting the business of disposing of the crops in the best market.

In making estimates for the size of intercepting sewers, conduits, pumps and area of land required, we have used as a basis a population of 2,500,000 people, with an average dry weather sewage discharge of 150 gallons, or 20 cubic feet, per head daily, and made provision for storm water equivalent to one-fifth of an inch in 24 hours over all portions of the district now drained or likely to be drained by a combined system of sewers, allowing surplus water to escape in the rivers and lakes.

The dry weather flow of sewage would therefore be 50,000,000 cubic feet per day, and the maximum flow of storm water 65,000,000 cubic feet per day, making a total maximum discharge of 115,000,000 cubic feet.

From an examination of rainfall tables we conclude that the annual amount of storm water that would be carried off by such an intercepting system would range from 9 to 12 inches, an average of which in round numbers may be taken at 40,000 cubic feet per acre per annum over the area drained by a combined system of sewers. It is practicable, however, to exclude the storm water from the sewers over a large portion of the future city

by adopting the separate system of sewerage. The area north of the town of Jefferson and of the middle of Lake View may be treated to advantage in this way, and also a large portion of Hyde Park, Lake Calumet and other adjacent towns.

Assuming that the area which does not allow the storm water to be entirely excluded is 140 square miles, the average daily amount becomes 10,000,000 cubic feet, which gives, when added to the sewage, 60,000,000 cubic feet, or 24 cubic feet per head of population per day to be provided for on the farm.

As the amount of land required to purify sewage can only be determined by experience, and as this has been very limited in our own country, we are forced to rely mainly upon that of Europe. Without going into details at present, we will simply state that a fair consensus of this experience justifies us in the conclusion that from 10,000 to 15,000 acres of land would be required to dispose of the sewage from the entire metropolitan area.

The only available territory for sewage filtration in the neighborhood of Chicago consists of two sandy ridges in the Town of Thornton, extending across the state line into Indiana, and in a sandy ridge crossing the Town of Niles. The soil is quite favorable, but the character of the surface is such that the necessary preparation to make it suitable for filtration beds would be comparatively expensive. An enormous cost is, however, represented by the fact that the sewage would have to be collected by large intercepting sewers, lifted altogether some 90 feet, and carried about 20 miles before reaching the farms. We therefore consider such a project entirely impracticable.

The land treatment can only be seriously thought of in connection with the sewage disposal from the smaller areas mentioned above and comprising the extreme northern and southern parts of the future metropolis. The drainage of parts of Evanston, Lake View and Niles might be taken to the sandy ground in the latter town, and that of the Calumet region to the sandy ridges in Thornton, should this method be found most advantageous when compared with others.

The preliminary investigation made for this purpose consisted in an examination of the grounds in the projection of a farm, and in an estimate of the cost of pre-

paring the same and delivering the sewage to it by intercepting sewers and conduits.

DISCHARGE OF THE SEWAGE INTO THE DES PLAINES RIVER.

A third solution of the drainage problem is rendered practicable by the fact that the divide between Lake Michigan and the Mississippi Valley lies about 10 miles west of Chicago, with so slight an elevation that it is not a difficult matter to carry the sewage from the city westward into the Des Plaines River, and thence into the Mississippi River. The method of disposal, as previously explained, is in fact mainly the present one, most of the sewage now being carried across the divide by the Illinois and Michigan Canal.

There are two low depressions between the future metropolis and the Des Plaines River—the Mud Lake Valley, with the present canal, and the Sag Valley west of Lake Calumet. Neither is more than 10 feet above the lake, nor do they present any engineering difficulties for canal construction. It is therefore quite feasible to carry all the drainage from the territory ultimately to be occupied by the metropolis, extending from Lake Calumet to Evanston, into the Mississippi Valley through these depressions, avoiding thereby all possible lake pollution and permitting the supply of water to be drawn from any number of convenient points in front of the city.

The possibility of this solution was recognized as early as 1856 by Mr. E. S. Chesbrough, and the first step towards its adoption was taken, as already mentioned, by turning the sewage into the Illinois and Michigan Canal. Not until quite recently, however, has it become practicable to consider the construction of a special waterway for sewage removal, because when the population was smaller the expense of the undertaking was too great.

The sanitary requirements demand a flow of water large enough to dilute sewage sufficiently to make it inoffensive along the river at all times. Beyond this, any increase in the size of the channel to provide for the storm water which naturally enters it should be kept at a minimum. A glance at the map and an examination of the ground show the possibility of diverting the greater part of the storm water from the metropolitan district without serious difficulty. Both branches of the Calumet River can be diverted west of the Indiana state line into Wolf Lake, and thence into Lake Michigan. The Des

Plaines River can have its flood water diverted into the North Branch near the north line of the Town of Jefferson, and the combined waters can be led from Bowmanville directly into the lake. Salt Creek, a branch of the Des Plaines River, can readily be turned southwardly near Western Springs, through a water course known as Flag Creek, at one time evidently its old bed, discharging into the Des Plaines opposite Sag, and thus reducing the necessary storm water capacity in the new channel between Sag and Summit.

In order to determine the probable quantity of flood water which can thus be excluded, it was necessary to ascertain the maximum flood discharges from all the watersheds in question. This requirement called for a gauging of Des Plaines, North Branch and Calumet Rivers; a gauging of the rainfall, which is a measure of the stream flow; a survey of the watersheds and an examination of the river channels. It was also necessary to make a reconnoissance of all possible lines for diverting the Des Plaines, the North Branch, the Calumet River and Salt Creek, and a survey of those which were most important.

The results indicate that each one of these diversions is both practical and economical. By adopting the "separate system" of sewerage for the territory lying north of the proposed Bowmanville channel, the surface drainage from this territory can be safely turned into the lake.

A second branch of the investigation extends to the elements governing the proper size of the waterway from which a large proportion of the storm water has been excluded. The area still draining into it will consist largely of paved streets and roofs, allowing of no absorption and shedding the water rapidly. It requires a careful consideration to determine the maximum quantity of water that may enter the proposed channel, and for which an ample allowance must be made to prevent a back flow of the polluted water to the lake.

The proper degree of sewage pollution in the new channel demanded a careful investigation. When sewage is mingled with a sufficiently large quantity of water it not only becomes inoffensive, but readily finds the oxygen which gradually purifies it. When the surface is covered with ice a greater dilution is necessary for this purpose than at other times when there is a constant

replenishment of oxygen from the air. The proposed waterway should, of course, provide immunity from offense at all times.

The information upon which definitely to decide this question will be given in the final report, as the data have not yet been all collected, owing to the necessity of making actual tests of the oxidization of the canal water under the ice, which is being done for the use of the commission by Dr. J. H. Rauch, secretary of the State board of Health. The summer conditions are presented in his late report on the water supply and sewage disposal of Chicago. The result of these analyses will be compared with those of other streams that are also polluted with sewage in order to show the rate of oxidization with varying degrees of dilution and aeration.

For the purpose of estimating the cost of the water channel we have assumed 3,600 square feet for the cross section and a velocity of the water 3 feet per second, or 2 miles per hour. This gives a discharge of 600,000 cubic feet of water per minute, or 24,000 cubic feet for each 100,000 persons, which we believe equal to the maximum requirements of a population of 2,500,000 people.

A third branch of the inquiry covers the selection of routes for the proposed canals.

Between Chicago and Summit three lines are practicable—one following the west fork and Ogden ditch, and another extending from the southwestern end of the south fork in a westerly direction to the Ogden ditch, and thence to Summit, and a third being an enlargement of the present canal. We are of the opinion that eventually both the first and second of these lines should be adopted, but that the second one should be built first in order to secure circulation in the south fork. From Summit westward the bed of the river and the present canal were the only lines to be considered. The best location has not yet been finally determined.

For the drainage of the Calumet region a simple inspection shows that a canal should start from the river at the southern point of Blue Island, and extend almost directly westward to the Des Plaines Valley at Sag.

A fourth branch of the inquiry relates to the study of such data as have reference to securing a proper circulation for the waterways within the city.

To throw light upon this point the variations of the lake level have been recorded since last spring by means

of an automatic gauge indicating an almost continual fluctuation, averaging several inches, and recurring at periods of about 20 minutes. During a low pressure of the atmosphere the amplitude of these oscillations increases, and not unfrequently reaches several feet. The accompanying diagram shows the level of the lake on August 16, 1886, at a time when an area of low barometer passed over it. From 6:40 a. m. to 6:55 a. m.—that is, in 15 minutes—the water fell 2 feet 10 inches.

A rising level causes an inflow to the river and drives the water of the latter into the slips, where it deposits a portion of its suspended sewage matter and becomes foul. A falling level reverses the flow, and the slips empty their foul water into the river and lake. During heavy fluctuations of the latter, such as the one referred to above, it has been traced more than a mile in the direction of the crib.

As the proposed canal from Bowmanville to the lake will lower the water of the North Branch at this point to the lake level, provision must be made for its circulation. The size of the Fullerton avenue conduit is not sufficient to furnish the water required for a current in both directions, nor would such an arrangement be satisfactory or economical. It will be necessary to establish a flow towards the South Branch from the lake opposite Bowmanville in order to prevent a future lake pollution by the proposed channel. This can be accomplished by placing a lock in the North Branch at any point that may be found most desirable and raising the water at the same time about one foot. If such a lock is placed at Fullerton avenue the present pumping works, with slight modifications, can be utilized.

Finally, it must be mentioned that circulation can be secured in the proposed waterways of the Calumet region, into which the sewage is discharged, by a gravity flow from Lake Michigan into the Des Plaines Valley through Lake Calumet and the Sag. The detailed features of this project have not yet been wholly matured the estimates of cost being based on a channel having a capacity of 1,000 cubic feet per second.

Comparison of Projects.

In the foregoing we have outlined the main features of the only three feasible methods of disposing of the metropolitan sewage, and have given the results of the investigation reached to date. A general conclusion as to the preferable method may be given at present, and also an approximate estimate of cost. But we are not able as yet to give either conclusions or detailed statements of the probable expense regarding all parts of the proposed work, and must defer them until the final report.

In comparing the projects we will first mention their probable cost and then their relative advantages.

The discharge of the sewage into the lake from a population of 2,500,000 in the manner described above, including the extra expense, otherwise not necessary, of taking the water supply of Grosse Point, would cost at least $37,000,000, with an annual expense for interest and operation of at least $2,400,000. It would require an immediate investment of about $20,000,000.

To dispose of the entire metropolitan sewage by filtration on land would require an investment of about $58,000,000, with an annual expense of over $3,000,000 for interest, pumping, and maintenance, after deducting the profit from the sale of crops. It would be necessary to invest at once about $34,000,000. Land disposal for the sewage from the Calumet region alone, with a future population of 300,000, would require an investment of about $4,000,000 and an annual expense of at least $250,000.

Finally, the cost of the Des Plaines project is approximately estimated as follows:

1. A channel from the South Fork to Joliet of the capacity heretofore given will cost between $17,000,000 and $21,000,000.

2. A diversion of the flood waters of the Des Plaines the North Branch, and Salt Creek will cost between $2,500,000 and $2,800,000.

3. Pumping works and locks for the North Branch will cost about $150,000.

Omitted; printed in House Ex. Doc. No. 264, 51st Cong., 1st sess.

4. A separate system of sewers to collect the sewage now discharged directly into the lake and to carry it into the river will cost about $600,000.

5. A channel from Lake Calumet to Sag will cost between $2,500,000 and $3,000,000.

6. A diversion of the flood waters of the Calumet River will cost between $350,000 and $400,000.

The total cost of the Des Plaines drainage project would therefore be, for the main district, between $20,-250,000 and $24,550,000; for the Calumet district, between $2,850,000 and $3,400,000. The annual cost, including interest, etc., is estimated at about $1,300,000 per annum.

The pollution of the lake can be decreased and the present condition of the Chicago River, and particularly of the South Fork, can be improved by the immediate construction of the following works, which, with the exception of the pumping works at the South Fork discharging into the Illinois and Michigan Canal, are all a part of the final plan.

1. Channels diverting the flood waters of the Des Plaines, North Branch, and Salt Creek, as described above.

2. A modification of the Fullerton avenue pumping station and the construction of locks for the purpose of getting circulation in the North Branch.

3. A separate system of sewers to collect the sewage now flowing into the lake from the south division and to discharge it into the South Fork.

4. A waterway extending from the western end of the South Fork to the Illinois and Michigan Canal, with a new pumping station to promote circulation.

5. By raising the banks of the canal and by removing deposits this capacity can be increased 40 per cent. at a small cost, and thus provide for a greater flow of water in the same.

The cost of the works comprised under these five items is estimated to be between $5,000,000 and $5,500,000. They could be finished in three years, and would greatly lessen the liability of polluting the water supply, while the sewage would be disposed of in the best practicable manner until the final completion of the Des Plaines project.

It therefore appears that this project is decidedly the least expensive one for the present as well as for the future.

Besides the economical advantages of the Des Plaines, scheme, its superiority is still further emphasized by advantages of another kind. The proposed canal will, from its necessary dimensions and its regular discharge, produce a magnificent waterway between Chicago and the Mississippi River, suitable for navigation of boats having as much as 2,000 tons burden. It will establish an available water power between Lockport and Marseilles fully twice as large as that of the Mississippi River at Minneapolis, which will be of great commercial value to the state. The Calumet region will be much enhanced in value by having a direct navigable channel to the Des Plaines River and by a lowering of the flood heights of Calumet Lake and River. Within the city the water of the Chicago River and its South Branch will get a much better circulation if it flows by gravity than if it has to be pumped, the necessity for which would remain even if the sewage should be discharged through intercepting sewers, either into the lake or upon land. Upon either of the latter conditions an occasional overflow from the sewers into the river during heavy rains would be more objectionable than a constant discharge of sewage into a more rapidly flowing stream. Flood waters entering the lake by way of the Chicago River would carry into it much filthy matter, either suspended or deposited, notwithstanding the existence of intercepting sewers, but the proposed diversion of such waters before reaching the populated districts will for all time obviate this undesirable occurrence. Lowering the level of the North Branch at Bowmanville by its diversion to the lake will be equivalent to raising the low prairie extending towards Evanston and Niles and greatly benefit parts of these towns.

The Water Supply.

In reaching the conclusion that the sewage of the city should be discharged into the Mississippi Valley the question of water supply is materially simplified, because the lake will then at all times furnish good water wherever intakes are desired for an extension of the works.

The preliminary inquiry made with a view to ascertain the main features of an increased supply, comprised first, a compilation of data concerning the existing works both in Chicago and its suburban towns, which were collected

mainly through the courtesy of the respective authorities; and, secondly, a study into the most economical method of distributing the water over the metropolitan area. The following is a brief description of the existing works:

The present intake for the public water supply of Chicago is located in Lake Michigan about two miles from shore and the water is conducted to the city in two circular brick tunnels 5 and 7 feet in diameter. They extend parallel to each other under the bed of the lake, and 50 feet apart, to the north pumping works, where they are connected and where the 5-foot tunnel terminates. The 7-foot tunnel is continued under the city for a distance of 20,500 feet, to supply the west works on Ashland avenue near 22d street.

The tunnels from the source to the shore are built at a depth of 80 feet below city datum, or low water in the lake, and the 7-foot tunnel is continued on the same level for a distance of about 11,500 feet, where, to avoid rock excavation, it is inclined upward until at the west pumping station, the top is but 21 feet below city datum. The economical capacity of the two tunnels is between 90,000,000 and 100,000,000 gallons per day, or less than the present average daily consumption of water. Their maximum capacity is reached when delivering about 150,000,000 gallons per day, which is now nearly equaled by the demand during the hours of greatest consumption, and at the present rate of increase it is estimated that during the summer of 1887 the maximum demand for water will be at the rate of 145,000,000 gallons per day; during 1888, 150,000,000 gallons per day; during 1899, 167,000,000 gallons per day; and in 1890, 180,000,000 gallons per day.

To provide against accident or obstruction from ice or other cause in the main tunnels, and to provide against an inadequate supply in the near future, which appeared inevitable, a new tunnel is in progress of construction. The intake is located 1,500 feet from shore, and connection is made with the other tunnels at the north pumping works.

The distribution of the water is effected by pumping it directly into the water mains at the north and west stations. At the north works the three tunnels are so arranged and constructed that any one of them can be emptied when desired for repairs or cleaning, and both the

pumping stations still be supplied with water from the other tunnels. The total pumping capacity of this station is at present 67,000,000 gallons per day, but it will be increased to 91,000,000 gallons per day as soon as the new pumps now in process of erection are in operation.

The connections between the pumps, standpipes, and the distribution mains at these works have become so complex by the successive additions to the plant that an unnecessary loss of head is the consequence. As this can be remedied to some extent without great expense, we recommend that it be done at the first favorable opportunity. The station being on the shore of the lake, is not centrally located with reference to any part of the city, which renders it necessary to use a greater length of main pipe, with a consequent loss of pressure, to reach the consumers than would otherwise be the case. The total pumping capacity of the west side station is 60,000,000 gallons per day, and the connections between the pumps, standpipes, and mains are simple and effective, and the loss of pressure from this cause is a minimum. The location is better adapted to secure economical and satisfactory results than that of the north works, and with reference to additional pumping stations, which will later be necessary in other parts of the city, these works are well situated.

The following table compiled from the annual reports for 1884 and 1885 gives a detailed comparison of the cost of pumping at two stations, anthracite coal being used at the north side and good bituminous coal at the west side:

COST OF PUMPING 1,000,000 GALLONS 1 FOOT HIGH.[a]

Nature of expenditures.	1884.		1885.	
	North Side.	West Side.	North Side.	West Side.
Salaries	$0.01488	$0.02022	$0.01560	$0.01667
Fuel	.05313	.02855	.04590	.02482
Lubricants ...	.00064	.00186	.00057	.00160
Miscellaneous.	.00323	.00417	.00133	.00401
Total	$0.07188	$0.05480	$0.06340	$0.04710

[a]Here appears a "diagram showing water pressure in the Chicago water pipes." Not here reproduced.

The hydraulic merits of the system are shown on the diagram of water pressures from a survey made in December, 1886. The pressures have all been reduced to a common height above city datum and to a uniform height of water at the works. That diagram shows a greater loss of head in the vicinity of the north side station than at the west side. This is accounted for by the complex arrangements heretofore mentioned, and also by the relatively small area of mains, being only 16½ square feet at the north side and over 21 square feet at the west side. Nearly equal quantities of water are pumped at each of the stations during the middle of the day.

The following table shows the pumping capacity of all the suburban towns having a public water supply, and the pressure ordinarily maintained at the works. With the exception of South Evanston, all take water from Lake Michigan.

Locality	Individual pump capacity. Pumps.	Individual pump capacity. Capacity per day. Gallons.	Total pumping capacity per day.	Ordinary head at pump, in feet.
Hyde Park	2	3,000,000	....	....
Do	1	12,000,000	18,000,000	103 to 150
Lake	2	4,000,000	....	....
Do	2	2,000,000	12,000,000	100 to 190
Lake View	1	5,000,000	....	....
Do	1	3,000,000	10,000,000	92
Do	1	2,000,000	....	92
Village of Evanston..	1	3,000,000	3,000,000	92
Total	11	....	43,000,000	....

At the artesian well supplying the village of South Evanston there is a head of about 53 feet.

The pressure at different parts of the pipe system is very irregular. In Hyde Park it varies from 165 feet at the pumps to 10 or 12 feet at Forty-third street. In the Town of Lake the average head at the town hall is reported about 10 feet, with 188 feet at the pumps. In Evanston, South Evanston, and Lake View the difference of head in various parts of the villages is not very great.

The following table gives a comparison of the consumption and cost of water in Chicago and the suburban towns:

Locality.	Year.	Average head at pumps.	Average daily pumpage.	Cost per 1,000,000 gals., delivered.	Cost of pumping 1,000,000 gals. 1 ft. high.
Chicago (North side)..	1885	113	38,369,134	$ 7.17	$0.06034
Chicago (West side)..	1885	105	53,280,880	4.95	.04071
Evanston (Village ...	1886	113	787,000	17.00	.15000
Lake View	1886	...	1,983,000	11.85	......
Town of Lake	1886	163	7,292,023	8.80	.05400
Hyde Park	1886	...	3,410,000	8.92	......

The second point of inquiry was a study into the most economical method of distributing the water over the metropolitan area. We will at present refer to it but very briefly, mentioning only such conclusions as pertain to the immediate demands and leaving a fuller discussion of the details of this important question to the final report.

The comparatively level area upon which the city is located, and the practicability of taking the water from the lake along the city front at any desired point, after the sewage has been diverted, permits the most economical distribution to be ascertained by mathematical investigation to a much greater degree of exactness than is usually possible.

It is found to be less expensive for the densely populated areas to have pumping stations about 2 or 3 miles apart, because the loss of head and cost of mains and pumping to obtain the least allowable pressure are thus reduced to a minimum. In planning new works this fact should be considered, and locations so selected that they will be advantageous for the future as well as for the present.

The localities which we believe to be most suitable for additional pumping stations are near 12th street, in the central part of the city; near the Union Stock Yards; near Humboldt Park, and near Fullerton and Racine avenues.

When it is considered that at the present time the pumps are delivering during the busy part of the day at the rate of 120,000,000 gallons in 24 hours, which is nearly the maximum capacity of all the machinery, and that even with this large consumption of water it is impossible in some parts of the city to obtain water in the second story

of the buildings, it becomes evident that an increased supply is imperatively required, and being a work of years to build new tunnels, inlets, buildings, and machinery, the necessity of deciding upon the location of the new works as soon as possible, is readily seen. The locality which is suffering most from the want of water is the business section and the south part of the city, the lowest pressure extending from 12th street to the city limits. It will become necessary in the future to have two stations in this territory, one between Harrison and 12th streets and the other to be somewhere east of the Union Stock Yards. We are strongly of the opinion that of the two stations it will be advisable and most advantageous to build the one north of 12th street first, for the following reasons:

1. It will require a shorter tunnel from the lake to the proposed station and less expenditure for main discharge pipes to connect with the present system than would be the case with the proposed southern station. This is equivalent to less cost and a saving of time in construction.
2. If the southern station is built first it will require mains of larger capacity leading toward the city than will be ultimately necessary when the central station is built.
3. The location recommended is near the center of the greatest consumption of water, and will be a gain not only in obtaining greater pressure in the business district, but in removing the cause for complaint on the south side by increasing the pressure so that the water will flow to the upper floors of the highest dwellings.
4. All other parts of the city will gain by the construction in this location, as the north and west works will be relieved of the enormous drain upon them to supply water for the business part of the city. They will be better able to give a good head on the north and west sides, where the population is increasing very rapidly, and which will very soon be in the same unsatisfactory condition as now obtains in the southern end of the city, unless relief is afforded in the manner indicated.

The other pumping stations will gradually become necessary as the population increases, and for a population of 2,500,000 there will be a need for a total combined capacity of 375,000,000 gallons to provide for a daily consumption of 150 gallons per head. With several in-

takes and tunnels the danger from stoppage of the water supply by ice or accident will be reduced to a minimum, as it is not probable that more than one of them would be so endangered at the same time.

We believe that a submerged intake will afford a more reliable and safer structure so far as injury from passing vessels and stoppage by ice are concerned than a structure projecting above the water.

With the sewage kept out of the lake there is no need of locating the intake farther than two miles from the shore where water can be obtained sufficiently free from suspended earthly matter, and where a depth of about 30 feet is generally found, which is the least depth desirable for a submerged inlet.

After presenting the results thus far gained, indicating the general solution of the Chicago drainage and water supply problem, it remains to point out certain facts which may be useful in discussing some of the legal measures required to carry out the proposed work. We desire to state that in order to reach the best results it is imperative to have all the main drainage works, such as intercepting sewers, waterways, and pumping stations, executed and maintained under a single management. It would be economical also to design and operate the main works for supplying water to the entire metropolitan area on a uniform plan and under one management, for the same reason that it is economical to keep the north and west side pumping works under one control, thus giving facilities as far as practicable for a supply proportioned to the demand to the entire metropolitan area, including the towns not bordering on the lake. We do not wish to imply, however, that such a general authority need necessarily extend further than to the construction and maintenance of the tunnels and conduits furnishing water to the respective pumping works.

Regarding the limits for metropolitan drainage, the investigation has shown, as already indicated, that topographical conditions clearly define two districts for the future metropolis. The main district extends from the line of 87th street on the south to the north line of Evanston and from the lake westward to the Des Plaines River. Its sewage is collected into one channel and discharged into the Des Plaines Valley at Summit. The Calumet district extends over the natural drainage area of Calu-

met Lake and River south of 87th street, and has its outfall channel running from Blue Island to Sag.

The final report will contain several maps, showing certain features of the metropolitan area, namely, the distribution of the population in 1886, the existing works and main distribution pipes for water supply, and the existing main sewage works and five-foot contour lines over nearly the entire area. It will also contain maps and profiles of the proposed waterways and storm-water-diversion channels mentioned in the present report, and a map showing the lines of the main collecting and intercepting sewers of the proposed drainage district, and also the lines of new tunnels and the general distribution of the water supply.

In carrying on the present investigation its various branches are placed in charge of the gollowing gentlemen, of whose ability and industry we desire to make special mention: Mr. L. E. Cooley, principal assistant, had special charge of the hydrographic work; Mr. Charles H. Swan, of the sewage disposal on land; Mr. Francis Murphy, of the topographical work; Mr. O. Guthrie, of the river pollution, land damages, etc., and Mr. T. T. Johnson, of the water supply, sewerage and miscellaneous work.

Respectfully submitted,
RUDOLPH HERING,
Chief Engineer.
BENEZETTE WILLIAMS,
SAMUEL G. ARTINGSALL,
Consulting Engineers."

I will ask you whether or not the statements in that report to which I have just directed your attention are the statements to which you referred in your direct examination as the ones which you made on this subject in the year 1887?

Mr. Williams: I object to the form of the question. I object to incorporating in the question the report referred to as not being proper cross-examination; and I object further on the ground that in the reports are statements referring to matters concerning which the witness has not been asked on his direct examination, and the entire question is improper as cross-examination.

A. They are.

Q. And the statements in that report which purports to be signed not only by yourself, but by Mr. Williams and Mr.

Artingstall represented at the time the report was made your own best judgment on the subjects with reference to which you have been testifying, did it not?

A. It did.

Q. That is to say the report is one which appears to be signed by three engineers, but so far as the report itself is concerned, it represents your judgment on all of the matters that are there set forth?

A. It does.

Q. Now, I will direct your attention to the report Appendix F, which appears on page 42 of this document to which I have last called your attention, the same being a report to the International Waterways Commission on the disposal of the sewage of Chicago and vicinity by Rudolph Hering and George W. Fuller under date of December 18, 1906, which is as follows:

"New York City, December 18, 1906.

To the International Waterways Commission:

Sirs: In response to your recent request we beg to report herewith upon several propositions connected with the question of extending the method of disposing of the sewage of Chicago and vicinity by means of dilution with Lake Michigan water. Your instructions may be briefly summarized as follows:

1. Examination into the sanitary situation at Chicago so far as it is affected by sewage disposal.

2. Latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive.

3. Is the extension of the dilution method to the outlying territory the only way to preserve the lives and health of the people of Chicago?

4. For the Calumet area, are there not other methods of sewage disposal which may be applied at a cost not exceeding much, if at all, the cost of the method of dilution proposed, and which will be equally effective in preventing the pollution of the lake water?

5. Description of the various systems of sewage disposal which are available for the Calumet area, with a statement of their relative efficiencies.

6. Statement of the approximate relative costs of the last mentioned so far as they can be given without the preparation of detailed plans.

You further state clearly in your letter of instructions

that you do not desire an investigation into the effect of the present method upon the navigation interests of the Great Lakes, as that has already been officially considered by yourselves. Further, you state that you accept as a fixed fact the Chicago Drainage Canal as designed and built, with its attendant diversion of 10,000 cubic feet per second of lake water through the Chicago River and its branches.

In accordance with further instructions we have not given consideration to questions of a legal or legislative nature. We have viewed this problem solely as an engineering proposition without regard to inter-state questions and other features associated with the fact that a portion of the future metropolitan area of Chicago will obviously lie within the State of Indiana. It is further understood that under the existing circumstances we are to give you our opinion without entering into such details as would be required by additional surveys or other field work beyond a personal inspection of the areas.

Sewage Disposal at Chicago.

Drainage Canal.—Nearly all of the sewage from the population of Chicago now connected with sewers is diluted with Lake Michigan water, which, since January 17, 1900, has been allowed to flow through the new drainage canal and thus reach the valley of the Illinois River. This method of disposal is the outcome of various investigations, particularly of a commission on the drainage and water supply of Chicago in 1886-87. It was formally adopted in 1889 by State legislation, creating the 'Sanitary District of Chicago,' specifically providing that the volume of lake water for purposes of dilution shall be 3⅓ cubic feet per second for each 1,000 of population connected with the sewers, or 20,000 cubic feet per minute for each 100,000 population.

Early Methods.—In early days part of the sewage of Chicago flowed directly into the lake and part into the Chicago River and its branches. From the latter a portion of the water and sewage, beginning over thirty-five years ago, has been pumped at Bridgeport into the Illinois and Michigan Canal, as is true to some extent today. It is understood that the old canal is to be discontinued by legislative action as soon as equivalent transportation and

power facilities can be arranged for by means of the new canal.

Area of Sanitary District.—In 1903 an act of legislature was passed extending the area of the sanitary district from 185 to 358.1 square miles, and including the 'North shore addition' of 78.6 square miles, and the 'Calumet addition' of 94.5 square miles. The area of the City of Chicago is 190,638 square miles, leaving 167,462 square miles as the area of the present sanitary district outside of the city limits.

There are several features to be noted in connection with the method of sewage disposal of the City of Chicago as adopted in 1889. It had been found to be the cheapest method then available for disposing of the sewage so that it would not pollute the public water supply, which was then and is now diverted from Lake Michigan through a series of intake cribs located at various distances from shore.

Intercepting Sewers.—To prevent such pollution it was of course necessary first to divert all of the sewage into the Chicago River. A pure water commission was appointed by the Mayor in 1897 to consider the question of intercepting sewers for that purpose. It recommended among others a large intercepting sewer to collect the sewage from the area along the lake front between Seventy-third and Thirty-first streets, and about a year ago a 20-foot conduit was completed on Thirty-ninth street, through which the diluted sewage from this area now passes to the south fork of the south branch of the Chicago River. At present there is a gravity flow of lake water ordinarily of about 40,000 cubic feet per minute. Pumps are now in process of erection by which ultimately there will be pumped through this conduit about 120,000 cubic feet of lake water per minute, or 2,000 cubic feet per second.

On Twenty-second street there was formerly a main sewer draining the area bordering on the lake front between Thirty-first and Sixteenth streets, and discharging into the lake. In 1898 the flow in this sewer was reversed so that its contents now discharge into the river.

On Twelfth street in 1898 the flow in the main sewer was also reversed.

In the heart of the city, or business section, the sewers have always discharged into the river and not into the

lake. The same is true of a considerable area lying north of the Chicago River and along the lake shore. To facilitate this discharge a conduit was put in service in 1880 at Fullerton avenue, through which there has been pumped about 12,000 cubic feet of lake water per minute into the North Branch of the Chicago River.

At the present time there is no sewage entering the lake between Surf street (just north of Lincoln Park) on the north side and Seventy-third street on the south side of Chicago.

Plans are under way for the construction of the necessary works to collect the sewage along the lake front between Seventy-third and Eighty-seventh streets and to pump it into sewers west of Halsted street, which lead to the Chicago River. There is very little or no sewage from this area now reaching the lake, as the district is yet practically unsewered.

On the north side there is an area between Surf street and the northern city limits and between the lake shore and the ridge between the lake and the river, which now discharges sewage into the lake, but which will be diverted next summer. This sewage is to be collected by interceptors conducting it to Lawrence avenue, where will be located a pumping station and a conduit for pumping the sewage and about 35,000 cubic feet of lake water per minute into the North Branch of the Chicago River.

Farther north, at Wilmette, a conduit is proposed to be built with a pumping station near the Northern Railroad bridge in Evanston, where about 60,000 cubic feet of lake water per minute will be diverted into the North Branch of the Chicago River.

Summary of Flow to Canal.—The projected flow of the lake water to the canal through the Chicago River and its branches to the Drainage Canal may therefore be divided and summarized as follows:

	Cubic feet per minute.	Cubic feet per second.
Main stream, Chicago River	373,000	6,217
Thirty-ninth street conduit	120,000	2,000
Fullerton Avenue conduit	12,000	200
Lawrence Avenue conduit	35,000	583
Wilmette conduit	60,000	1,000
Total	600,000	10,000

The volume for the main stream of the Chicago River as above stated is obtained by deducting the remaining quantities from the total.

The satisfactory disposal of the sewage of Chicago by means of the new drainage canal requires that, at and after heavy rainfalls, the storm water and sewage from the watershed of the Chicago River shall not flow into Lake Michigan, and therefore it is necessary to secure a practical reversal of the original flow in the Chicago River.

The drainage area of the Chicago River is about 270 square miles. Flood flows in the river have reached a maximum of about 10,000 cubic feet per second, or 600,000 cubic feet per minute, and this fact was also an important element in fixing the minimum size of the present drainage canal.

As to the efficiency of arrangements for the reversal of flow, our inquiries lead us to believe that this has been accomplished in a satisfactory way. Up to the present time, and owing to the insufficient waterway of some parts of the Chicago River, the volume of Lake Michigan water going through the river has not approached the volume above stated. But there have been times when a continuous flow of the Chicago River has been toward Lake Michigan for perhaps two or three hours. This time is necessary to properly regulate the water level at the controlling works near Lockport.

Population of Chicago Now Sewering Into the Drainage Canal.

We find that the present population of Chicago is, in round numbers, 2,000,000 people, of which between 100,000 and 200,000 reside south of Eighty-seventh street, tributary to the Calumet district, but within the city limits. Of the remaining population about 300,000 reside in the southern lake front district. This area is tributary to the Thirty-ninth street pumping station, which, since about January 1, 1906, has brought about the diversion of the sewage from the lake into the South Fork of the south branch of the Chicago River.

There is still an area in the northwestern part of the city north of Lincoln Park, spoken of as the northern

lake front district, which drains directly into the lake. Its population may be very roughly estimated at 70,000.

There is a considerable area south of Seventy-third street and west of Halsted street, and also a portion of the northwestern part of the city, which are of a semi-suburban character. Some portions have been provided with sewers and receive the overflow from cesspools.

So far as we are able to ascertain from local officials and without making a personal canvass as to details, it appears that there are now, in round numbers, about 1,500,000 people sewering into the drainage canal. In addition to the sewage there enters it a considerable quantity of trade wastes, notably about 2,000,000 gallons from the stock-yard district, and from quite a number of other industrial establishments, such as tanneries, wool-pulling establishments, etc., as stated by the sanitary inspector in the last report of the health department.

It is our understanding that the present sewage disposal project for Chicago is not intended to provide for the disposal of trade wastes now discharged into the sewers. While comparatively little has been done as yet to remove them from the sewers, we have been informed that it is proposed to take up this matter actively.

Influence of Sewage on Chicago Water Supply.

The City of Chicago receives its water supply from Lake Michigan through a series of tunnels of various lengths, ranging from about one to five miles from shore. Most of them extend from the shore about two miles. The total pumping capacity for this supply is stated to be 529,000,000 gallons in twenty-four hours. In 1905 the average daily pumpage was recorded as 399,000,000 gallons.

Since the removal of the sewage through the drainage canal was systematically begun in January, 1900, the appearance of the water of the Chicago River has shown marked improvement.

The effect of the drainage canal upon the hygienic quality of the public water supply may be studied in connection with the typhoid fever death rates at Chicago, which are recorded in the next table, together with corresponding death rates for a number of other American cities. It is not to be assumed

that typhoid fever is entirely due to the pollution of the public water supply at Chicago or elsewhere, as it is well known that there are other means of transmitting this disease. But its relation to the public water supply is so intimate that it gives, perhaps, the best general idea of the sanitary quality of the water, and therefore it frequently has been used as a rough means of such measurement.

There are other factors besides the drainage canal to be considered carefully in connection with the typhoid fever statistics at Chicago, and some of which should be mentioned here. Prior to 1900 there was a substantial improvement in the public water supply, partly due to the extension of some of the intake cribs and tunnels farther into the lake and partly to the reversal of the flow of a number of sewers from the lake into the river, such as those at Twelfth and Twenty-second streets, in 1898. These are important factors in explaining the absence in the late nineties of such excessive typhoid death rates as were noted at the beginning of that decade.

Since the opening of the drainage canal typhoid fever in Chicago has been rather unusually prevalent at times. This was especially true in 1902-3, when, it is understood, portions of the supply became contaminated after leaving the intake crib. These accidental pollutions have since been corrected.

The report of the city chemist of Chicago, as given in the last annual report of the department of health, shows that on an average in 1905 the city water supply was considered by him to be safe about 85 per cent of the time.

While there has been a marked improvement in recent years in the quality of the Chicago water supply, due to the progressive elimination of sewage from the lake, there is still room for more improvement. These improvements refer to the pollution along the lake front north of Lincoln Park, which is being corrected, and to the "Calumet area" south of Eighty-seventh street, which is now under consideration.

COMPARISON OF THE ANNUAL NUMBER OF RECORDED DEATHS FROM TYPHOID FEVER PER 100,000 POPULATION AT CHICAGO AND OTHER AMERICAN CITIES, 1890-1905.

Year.	Chicago.	Milwaukee	Detroit.	Cleveland.	Buffalo.	Toronto.	Boston.	New York.	Philadelphia.	Baltimore.	Washington.
1890	83	33	18	69	44	80	43	21	64	57	89
1891	160	33	13	50	56	90	33	22	65	34	86
1892	103	31	64	59	38	40	25	14	40	42	72
1893	42	37	29	52	37	40	26	20	40	47	72
1894	31	26	27	29	62	20	23	17	32	49	72
1895	32	25	24	35	28	30	32	17	40	28	69
1896	53	18	23	43	22	24	32	16	34	37	51
1897	29	11	15	23	19	18	33	16	33	37	42
1898	38	17	18	34	29	16	34	20	51	38	64
1899	26	17	13	32	26	19	30	16	75	30	82
1900	20	21	18	54	27	19	25	21	35	37	77
1901	29	21	20	36	27	16	25	20	33	27	67
1902	44	16	17	33	33	13	35	21	44	42	79
1903	31	17	17	114	35	15	20	18	70	36	48
1904	19	13	16	48	91	22	18	17	..	36	43
1905	16	20	12	15	23	..	20	16	48	36	45

LATEST CONCLUSIONS AS TO THE REQUIRED DEGREE OF DILUTION FOR THE DISPOSAL OF SEWAGE WITHOUT NUISANCE.

The disposal of sewage by dilution depends on the amount of oxygen in the diluting water being sufficient to prevent putrefaction of the organic matter in the sewage as the latter undergoes bacterial decomposition. If the oxygen is deficient bacterial decomposition produced what is called "putrefaction," with its various attendant bad odors, such as noted for years in Chicago at "Bubbly Creek." If there is a sufficient amount of oxygen dissolved in the water to combine with this organic matter, decomposition goes on without any foul odors and the organic matter is reduced to inert matter in an inoffensive way.

This question is one of balancing the amount of oxygen in

a given volume of water with the amount of decomposing organic matter in the sewage, which naturally must vary greatly.

There are many observations of more or less accuracy available to give figures for this relation. The Massachusetts State Board of Health made a special inquiry into this subject for all local rivers in 1902, with conclusions, stated on page 452 of their annual report for that year, as follows:

"The results of the investigations show that where the quantity of water available for the dilution of the sewage in a stream exceeds about six cubic feet per second per 1,000 persons discharging sewage, objectionable conditions are unlikely to result from the gross pollution of all the water of a stream in dry weather. Under favorable circumstances, such as in cases where the sewage is discharged at many outlets into a large body of water, objectionable conditions may not result where the dilution is somewhat less than six cubic feet per second per 1,000 persons; but objectionable conditions have resulted in all of the cases thus far examined where the flow has been less than 3.5 cubic feet per second per 1,000 persons discharging sewage into the stream."

These conclusions apply for the most part to comparatively small streams into which much manufacturing waste is discharged and upon which mill ponds are situated.

There are times when the flow of water in the drainage canal appears to have been insufficient to eliminate objectionable odors entirely. How far this may be explained by confusion on the part of observers of the putrefactive odors emanating from the Illinois and Michigan Canal with those of the new canal, and how far it may be due to temporary reductions in the rate of flow in the new canal and river to facilitate constructive work, and also to the effect of rainfalls and to old deposits in the South Fork, we are unable to say.

The new canal appears to serve at present about one-half the population for which it was designed, and through it flows a volume of lake water which is variable, but which averages not far from one-half of the ultimate quantity.

It is our judgment that for large canals with the trade wastes eliminated a dilution of 3 1-3 cubic feet per second for each 1,000 population connected with the sewers also receiving storm water is as low a figure as it is now possible to state. Local conditions, especially temperature, which affects bacterial activities and the coefficient of absorption of oxygen by water, and still other matters, bear upon this question, the detailed discussion of which is not now neces-

sary. We feel certain that a dilution of 2 1-2 cubic feet per second would cause offenses at times, and probably also a dilution of three cubic feet per second.

Future Population on an Area Tributary to the Chicago River and Drainage Canal with Reference to Sewage Disposal.

On the basis of the diversion of 10,000 cubic feet per second of Lake Michigan water, on the present assumption of 3 1-3 feet per second as being the volume to be provided for each 1,000 population connected with the sewers, and on the assumption of eliminating objectionable trade wastes, the present method of disposal may serve until the population on the drainage area of the Chicago River reaches 3,000,000 people.

On the further assumption that through the Chicago River and various conduits connected with its branches there will be a flow equal to 14,000 cubic feet per second, which is the capacity of the rock section of the drainage canal, the maximum population which might be taken care of in this way is about 4,200,000 people.

With a large portion of the 270 square miles draining into the Chicago River, but not yet built up, even on a suburban basis, it is evident that in future years there will be a much greater population than now exists.

We have considered the rate of growth in Chicago from various viewpoints, notably the density of its population, and have compared its growth with that of other metropolitan districts. There is, of course, no way of predicting accurately how rapid will be the growth of Chicago in future years; but it is a reasonable assumption that before many years it will become a city of some five or six million of population. It seems reasonable to infer that the population residing upon the area tributary to the Chicago River and its branches will ultimately exceed both the 3,000,000 and 4,200,000 estimates above mentioned. In other words, the present dilution method will certainly not alone for all time take care of the crude sewage of this area.

There are several available methods for the purification of sewage, depending upon the degree of purification desired, as will be noted beyond in connection with the Calumet area.

It is not probable that the sewage of the old part of Chicago will ever be purified by artificial means, as it would be proportionately much more difficult and expensive to deliver

the sewage to suitable sites for purification than to continue the present dilution method. It is different with the outlying districts tributary to the Chicago River. In the future, when these districts become built up so that the population exceeds the limits above stated, the installation of sewage purification works will necessarily follow.

The more essential feature of this proposed canal, as obtained from local officials, may be summarized as follows:

Location.—The canal would extend from a point on the Little Calumet River near Blue Island, through the Sag Valley, and enter the drainage canal near Sag Station.

Territory Tributary.—The total drainage area of the Calumet River is 825 square miles, of which 473 are in Indiana. Within the limits of the sanitary district of Chicago and south of Eighty-seventh street, the area is 94.5 square miles, with a population of about 100,000 in 1900. It is stated that the population has nearly doubled within the past six years, and it is expected to reach a million people or more within a fairly short period, as the conditions for a manufacturing district are very favorable.

Size.—The size of this canal, as proposed, is such as to give a flow of 4,000 cubic feet per second.

Reversal of Flow.—The natural flow of the Calumet River exceeds 12,500 cubic feet per second. It is proposed, if suitable legislation can be secured, to construct a dam below Thorn Creek, at the southern boundary of the sanitary district, and divert into Lake Michigan, through a channel to be built about 17½ miles east of the state line, the flow of this stream, with a drainage area of about 587 square miles. The size of the proposed Calumet Canal is too small to secure at all times a reversal of flow of the remaining portion of the area, which is about 240 square miles. It is proposed to put a controlling lock on the canal east of Blue Island to prevent flood waters from this low area entering the canal, at which times sewage entering the river on the lake side of the lock would go into the lake.

The proposed canal is insufficient to carry in the future all the storm flows of the Sag Valley itself. These would, at least, in part, require diversion through present or other channels.

Cost.—The estimated cost of this proposed canal is $12,-000,000.

Population to be Served.—On the assumption already stated, this canal, by dilution, would dispose of the sewage

of about 1,200,000 people, not including objectionable trade wastes. This makes the cost of sewage disposal $10 per capita for the entire future population, or about $60 for the present population. The sewage would for the most part reach the canal by gravity through the Calumet River, so that the cost of maintenance would be comparatively small.

In passing, we may say that the Calumet area, both in Illinois and Indiana, is certain to develop rapidly, and its population will eventually far exceed the above figure.

Relation of Sewage Disposal for the Calumet Area to the Water Supply of Chicago.

For the reasons above stated in connection with the reversal flow, the sanitary effect upon Lake Michigan water at the Hyde Park intake and vicinity of this proposed Calumet Canal would not be nearly as effective as that of the main canal for the Chicago River territory and neighboring intakes. This fact is important in connection with the degree of sewage purification required by artificial purification works to give a sanitary effect equal to that of the proposed canal.

There seems to be no doubt that at times the sewage entering the Calumet River under present conditions from this district pollutes the lake water from the Hyde Park intake crib. It may pollute the water at other intakes, but our evidence is not conclusive. In the future, when the Calumet area is built up, it is possible that intake cribs may be built nearer to the mouth of the Calumet River than is the Hyde Park intake.

In view of the fact that the proposed Calumet Canal can not keep all sewage out of Lake Michigan at times of heavy rainfall, it is important to note that the water supply of this section of Chicago will eventually have to be purified by modern filtration works. This can be done at moderate cost, and it will be the cheapest and best solution of this problem to filter the water supply of this district and to purify the sewage to such a degree that the effluent will be fairly clear and nonputrescible, that is, free from disagreeable odors. With additional expense the sewage effluent (of the quality just stated) can be given a supplementary purification, making it practically free of bacteria by treating it with a germicide or by filtering it according to water purification practice.

Under existing conditions we are firmly of the opinion that

all the purification required of the sewage of the Calumet district is to make it fairly clear and non-putrescible.

Available Methods of Sewage Disposal Other than that of the Dilution Method Proposed for the Calumet Area.

The degree of purification of sewage by various forms of treatment differs naturally under different local conditions, but from general experience approximate results may be compared, substantially as follows:

Method.	Percentage purification. Suspended matter.	Organic matter.	Bacteria.
Fine screens (30-mesh or finer)..	15	10	15
Sedimentation	65	30	65
Septic treatment	65	30	65
Chemical precipitation	85	50	85
Contact filters*	85-90	65-70	80-85
Sprinkling filters*	85-90	65-70	90-95
Intermittent sand filters*.......	95-99	90-98	98-99

*The figures for the last three forms of treatment are on the assumption that the sewage is given some form of preparatory treatment before it is applied to the filters, and that with the sprinkling filters the effluent is allowed to settle.

It is to be stated that none of the first four treatments above tabulated will by itself give a non-putrescible effluent. Therefore they can be used here only in connection with some form of filtration.

For large works filters can be more economically operated if the sewage is first clarified in part, as stated in connection with the above summary. The most appropriate method for this preparatory or preliminary treatment is considered by most sanitary engineers in this country and abroad to consist of septic tanks, which is the expression applied to sedimentation basins in which the deposited sludge is allowed to accumulate to undergo bacterial action.

There are several forms of filters, the most widely known of which, in this country, is the intermittent sand filter sometimes mentioned as the so-called "land treatment" for sewage disposal. This method was considered in 1886-87 for the entire Chicago area and reported upon unfavorably on

account of its being more expensive than the adopted method of dilution.

Local Experiences.—We find that a feeling appears to prevail among some persons at Chicago against land treatment of sewage, due perhaps to the unsuccessful operation of the sewage farm at Pullman, which is situated within this Calumet area.

We are familiar with the facts and experiences at Pullman, and are clearly of the opinion that they are not necessarily a criterion for the Calumet area. This opinion is based partly upon the small size of particles of the soil at the Pullman farm, and partly upon the fact that the farm was devoted principally to agricultural rather than sewage purification purposes.

Sand Areas.—We have examined the tracts of lake sand which are found in Indiana and to a limited extent in the township of Thornton, Ill. The latter areas are too limited in extent and too shallow to be considered for present purposes. The only areas of suitable porous sand for land treatment of the Calumet sewage are in Indiana.

We have collected five samples of this sand for mechanical analysis, and have obtained the results as to size of sand grains. Representative results average substantially as follows:

	Millimeters.
Effective size	0.15
Uniformity coefficient	1.45

If we disregard the state boundary line, a large tract of sand of a suitable character is available for the disposal of the sewage of this district. The best area lies between the Little Calumet and the Grand Calumet rivers, and extends east of Hammond for many miles.

Within the past six or eight years great strides have been taken in the field of sewage purification in connection with works of wholly artificial construction. We refer particularly to filters of coarse, firm material, such as broken stone, slag or clinker, and usually spoken of as "coarse-grained filters," as distinguished from fine-grained sand filters.

Coarse-grained filters are of two types, spoken of as "contact filters" and "sprinkling filters," according to the method by which the sewage is applied to them. These filters produce an effluent which will not putrefy when they are operated at a rate far greater than that which is possible for sand filters.

We shall describe briefly each of these types of sewage-purification methods and state their approximate cost of construction on suitable sites for the Calumet area, based upon unit prices in accordance with experience elsewhere.

An outline is first required, however, of the intercepting sewers, pumping stations, and rising mains necessary to collect and deliver the sewage to the filter sites, of which there are several available.

Regardless of the particular kind of filter found most suitable for the Calumet area, there are a number of features common to all methods, and which may be stated as follows:

SEPARATE SEWERS.—With the adoption of sewage filters for this district we are clearly of the opinion that it would be advisable hereafter to build a separate system of sewers for domestic sewage only. Some, if not all, of the existing main sewers could be used for the removal of storm and surface water only, and new sewers parallel them for sewage removal; or, some of the existing sewers could be utilized for sewage removal, requiring new structures for storm-water removal. Trade wastes should be excluded from all sewers. We have obviously not included in the cost of purifying the sewage any expense for the main sewers or laterals to collect it and deliver it to the interceptors.

VOLUME OF SEWAGE.—We have assumed that the sewage of this district will approximate 130 gallons per capita daily on an average. With a population of 1,200,000 the total volume of sewage would therefore be about 156,000,000 gallons daily. We have also allowed for ground-water seepage up to 1,000 gallons per square mile per day.

INTERCEPTORS.—For purposes of making approximate but liberal estimates of cost of purifying the sewage of this district, we have prepared sketches showing the intercepting sewers which will be required in order to collect the sewage of the district at four or more centrally located pumping stations. We have assumed that these intercepting sewers will be built of concrete, and when flowing full have a capacity of 250 gallons per twenty-four hours for each person resident upon the area tributary to the interceptor. When full, these interceptors have been assumed to have a velocity of 2.5 feet per second. We have also assumed, after excluding that portion of the Calumet district reached by extreme high water in the lake, that on an average the population contributing to the four or more pumping stations would be about 20 to 25

persons per acre. On this basis the length and size of the necessary intercepting sewers have been obtained.

Pumping Stations.—For convenience we have located four main pumping stations near Riverdale, Harvey, South Hammond, and South Chicago. There will be required, when the district is built up to the extent herein considered, a total pumping capacity of about 340,000,000 gallons daily, including necessary reserve capacity at each station.

Septic Tanks.—Regardless of the type of filter adopted, the sewage would be screened at the pumping stations, and then flow through septic tanks having a capacity of eight hours' flow on an average. These tanks would be about 12 to 15 feet deep, built of concrete, and arranged in compartments, so as to facilitate septic action on the deposited sludge, but without such action taking place in the flowing sewage itself. Owing to the severe winter climate in this vicinity, it is our opinion that it would be wise to cover these tanks.

Of the solid matters in suspension in the sewage about 65 per cent would deposit in the septic tanks, and of these deposited solid matters about one-half would be liquidified and gasified by bacterial decomposition.

The sludge which would be removed at intervals of once a year or so from the tanks, is estimated to contain about 85 per cent water and to amount to about 2 cubic yards per 1,000,000 gallons. Bacterial action converts this sludge to a practically inert mass which can be pumped in thin layers on to adjoining land and allowed to dry.

This is the form of preliminary treatment in use in some 40 places in this country, including Plainfield, N. J., Saratoga, N. Y., Mansfield, Ohio, Champaign, Ill., etc. It is the preliminary step in the works under construction at Columbus, Ohio, after elaborate tests of different methods were made for a period of nearly one year. It has also been adopted recently at Baltimore, Md., Reading, Pa., and Waterbury, Conn., and has been recently proposed for Paterson, N. J., in a somewhat modified form.

This form of preliminary treatment has been and is now extensively used in Europe with satisfactory results where the tanks are built and operated to meet local conditions as to volume and strength of sewage.

The odors from large open septic tanks are seldom noticeable a few hundred feet away. Under good management a septic effluent can be applied to sprinkling filters so that no objectionable odors should be carried one-quarter of a mile.

The cost of building and operating septic tanks would be substantially the same for all filter projects, and is considered under each as a common factor.

Intermittent Sand Filters.

This well-known method consists of applying the partially clarified sewage coming from the septic tanks to areas of porous sand, below the surface of which at depths of from three to five feet are underdrains of open-jointed pipe to convey the purified sewage to the nearest water course. The sewage is applied only at intervals of once a day or so to a depth of perhaps six inches. Between applications the sand layer is allowed to drain so that its pores may fill with air. This aeration of the pores of the sand allows bacterial processes to convert the organic matter to a large extent to harmless mineral matter. The effluent is practically free of noticeable suspended matter and objectionable organisms and can be discharged directly into the nearest water course.

This method is now in successful use in 40 to 50 places in this country where porous sand areas are available. It serves a total population of about 350,000 people. Well-known plants are to be found at Framingham, Brocton, Clinton, and Worcester, Mass.; Pawtucket and Woonsocket, R. I.; Meriden and New Britain, Conn.; Saratoga, N. Y., etc.

From time to time it is necessary to rake, harrow, or plow the surface of intermittent sand filters and to remove the scum which slowly accumulates there. At intervals it is necessary to scrape off several inches of the upper portion of the sand layer when it is found that they are so clogged that harrowing and plowing no longer prevents the surface from remaining covered with sewage.

With crude sewage it appears from Massachusetts evidence, especially from the tests conducted for a period of nineteen years at the Lawrence Experiment Station, that it would be necessary to provide one acre of intermittent sand filters for each 500 persons connected with the sewers. When the sewage is given a preliminary treatment in septic tanks and when the filters are operated under intelligent supervision the area may be reduced so as to provide one acre per 1,000 persons.

The most suitable natural site for sand filters for the Calumet area is to be found in the State of Indiana, between the Little Calumet and the Grand Calumet rivers, east of the City of Hammond.

It is possible to build artificial sand filters within the Calumet district, but the cost would be much greater than for any of the projects considered in this report.

Based upon our knowledge of these filters elsewhere, and without considering interstate complications, we estimate that the cost of installing and operating such a plant, with its various appurtenances, east of Hammond, and of a capacity of about 180,000,000 gallons daily to serve a population of 1,200,000 people, would be as follows:

Estimated Cost of Constructing Sand Filter Plant and Appurtenances.

Intercepting sewers, pumping stations, and appurtenances, including a daily capacity of 340,000,000 gallons, and rising mains	$5,070,000
Septic tanks, 60,000,000 gallons capacity, covered, including sludge disposal facilities	950,000
Intermittent sand filters, 1,200 acres, with distributors, drains, office laboratory, etc.	3,600,000
	$9,620,000
Contingencies and supervision, 15 per cent	1,443,000
Total	$11,063,000

Annual Cost of Operation.

Pumping, fuel, labor and repairs	$300,000
Supervision, analytical and clerical assistants, etc.	25,000
Care of septic tanks, including sludge disposal	36,000
Care of sand filters	480,000
Supplies and miscellanies	25,000
	$866,000

Capitalizing the operating expenses at 5 per cent per annum there is obtained $17,320,000, which, when added to the estimated construction cost, makes a total sum of $28,383,000 for the sand-filter project.

Contact Filters.

These filters consist of beds of broken stone, slag or cinders, placed in uncovered basins to a depth of from three to five feet. The size of material ranges from about one-fourth to one inch.

The filters are ordinarily operated upon the fill and draw plan, that is, the gate on the outlet pipe is closed until the voids of the bed are filled with sewage from the septic tanks. After filling, the filters are allowed to stand full for an hour or so, then the sewage is allowed slowly to drain out, and this cycle of operation is repeated once or twice a day.

When the filtering material is drained the voids fill with air, and it is during these periods of draining that bacterial processes accomplish the purification of the organic matter, which to a large degree is lodged upon the surfaces of the filtering material as the sewage is slowly withdrawn from the bed. The rates of filling and drawing the beds may be satisfactorily controlled by a number of automatic devices on the market and which are in successful use in a number of places.

Contact filters are an English adaptation of studies made some fifteen years ago upon the gravel filters by the Massachusetts State Board of Health at the Lawrence Experiment Station. These studies were begun about thirteen years ago at London. As an outcome of these and numerous other investigations, contact filters have been adopted and are in successful use for dozens of English cities, the largest of which is Manchester, with a population of about 600,000.

In this country contact filters have been installed for a dozen or more small cities and numerous institutions. Perhaps the best known plants are at Plainfield, N. J., Mansfield, Ohio, and Charlotte, N. C. They are especially applicable to projects where only a small amount of head is available and where pumping would be required for sprinkling filters.

For large projects, and where pumping is not a factor, recent experiences with sprinkling filters show that as a rule they are more economical. Notwithstanding this, contact filters have served and will serve a useful purpose in the field of sewage disposal in this country. Their convenience of operation makes them especially suitable for small installations.

Many contact-filter plants have their beds arranged in terraces so that the sewage may be passed successively through

two or three filters. There are a number of advantages of this arrangement, but it is not applicable to the Calumet district, owing to the level area of the available sites. One of the advantages of the double and triple contact filters is that they may be operated from below during winter weather and thus guard against reduction in the rate of filtration due to freezing.

The most available and suitable local sites are: A tract west of Harvey and between the Illinois Central and Rock Island railroads; a track west of Hammond and the local branch of the Fort Wayne Railroad, and a tract between lakes Calumet and Wolf.

As to the rate of filtration, we have assumed that contact filters should be five feet in depth and that they would satisfactorily purify the effluent from septic tanks at the rate of 600,000 gallons per acre per twenty-four hours. This means that one acre of contact filters should be provided for every 4,000 persons connected with the sewers.

The effluent from contact filters operated under these conditions would be ordinarily free from objectionable amounts of suspended matter, and the amount of organic matter would be so reduced that it would not putrefy upon standing. On an average about 15 to 20 per cent of the bacteria in the crude sewage would be present in the effluent. It would not be improper to discharge such an effluent as it came from the filters directly into the nearest water course.

The amount of attendance required for contact filters is not great, and is covered mainly by the necessary gatemen, analysts, and foremen. At intervals of all the material would have to be removed from the filters, washed, and replaced.

The approximate cost of building and operating a contact-filter plant with all needed appurtenances of a capacity of about 180,000,000 gallons daily to serve 1,200,000 people may be estimated as follows:

ESTIMATED COST OF CONSTRUCTING CONTACT-FILTER PLANT AND APPURTENANCES.

Intercepting sewers, pumping stations, and appurtenances, including a daily capacity of 340,000,000 gallons, and rising mains	$3,300,000
Septic tanks, 60,000,000 gallons' capacity, covered, including sludge, disposal facilities	950,000
Contact-filters, 300 acres, with all piping, appurtenances, office laboratory, etc.	6,000,000
	$10,250,000
Contingencies and supervision, 15 per cent......	1,537,500
Total	$11,787,500

ANNUAL COST OF OPERATIONS.

Pumping, fuel, labor, and repairs	$200,000
Supervision, analytical, and clerical assistants..	30,000
Care of septic tanks, including sludge disposal....	36,000
Care of contact-filters	260,000
Supplies and miscellanies	25,000
Total	$551,000

Capitalizing the operating expenses at 5 per cent per annum there is obtained $11,020,000, which when added to the estimated construction cost makes a total sum of $22,807,500 for the contact-filter project.

SPRINKLING FILTERS.

Sprinkling filters differ from contact filters principally in the method of application of sewage, which in our northern climates is discharged upon them in the form of spray from a series of fixed sprinkling nozzles placed about 12 to 15 feet apart. The filters are usually deeper and of somewhat coarser material than contact filters.

These filters are also an English adaptation of the Lawrence investigations with gravel filters some fifteen years ago. The English studies began at Salford in 1892 and have resulted in the adoption of this form of filter for many of the principal cities of England, the largest of which is the metro-

politan district of Birmingham, with a population of over 900,000. Some of these filters have been in successful practical operation for more than eight years. On the Continent this method is being adopted for portions of the suburbs of Paris and Berlin.

In this country this method has been studied with care at Lawrence, Mass.; Columbus, Ohio; Boston, Mass., and Waterbury, Conn. Filters of this type are now under construction at Columbus, Ohio, and Reading, Pa. They have been recently adopted for Baltimore, Md.; West Chester, Washington, Pa., and Waterbury, Conn. They have been recommended for use also at Paterson, N. J.

The important element of aeration is secured in sprinkling filters partly by applying the liquid as a spray and partly through the use of coarse material with voids of a size so that there is a vertical circulation of air through the filtering material at all times.

Suspended mineral and organic matters and some of the dissolved organic matters are retained upon the surface of the filtering material as the liquid passes in thin films over the surface of the particles. Bacterial activities reduce the organic matter to a material degree, and from time to time the remaining inert material cracks and peels and passes through the filter bed to the bottom. In order to be able to remove this accumulated matter, it is necessary to provide false bottoms for these filters. Filters of this type have been in successful use for more than eight years, without cleaning, and it is believed that under favorable conditions cleaning is not required oftener than once in ten or fifteen years.

The amount of suspended matter in the effluent of sprinkling filters due to this unloading of stored material is sufficient to require passing the effluent through settling basins, holding about two hours' flow, before discharging into the nearest water course. The settled effluent, of satisfactory appearance and with its organic matter so reduced that it will not putrefy, usually contains less than 10 per cent of the bacteria in the crude sewage.

There is a considerable range in size of broken stone and in depth of material as adopted in various large plants now built or building. Avoiding extremes, it may be stated that the depths average about seven feet, and the size of material ranges from about one to 2½ inches, mean diameter. We have assumed these figures for sprinkling filters for the Calumet area, to be built of broken stone at the sites already men-

tioned for contact-filters, namely, west of Harvey, west of Hammond, and between Lakes Calumet and Wolf.

We have carefully considered the climatic conditions at Chicago, and compared them with temperatures where practical experience with sprinkling filters have been obtained. There is no trouble from the freezing of the sprinkler nozzles through which sewage is applied under a head of six or seven feet. During zero weather some frozen sewage accumulates on the surface of the filter and at such times it is necessary to have some reserve area. We have assumed that under these local conditions one acre of sprinkling filters should be provided for every 15,000 people connected with the sewers, making a rate ordinarily of about 2,250,000 gallons per acre per 24 hours. As was demonstrated at Columbus, such rates for several weeks at a time may be doubled and still obtain a satisfactory non-putrescible effluent. This rate, expressed in persons served per acre-foot of sprinkling filter material, is only about one-half of that provided for at Columbus, Ohio, and one-third of that in several plants in England.

The approximate cost of building and operating a sprinkling filter plant with all needed appurtenances, of a capacity of 180,000,000 gallons daily, to serve a population of 1,200,000, may be estimated as follows:

Estimated Cost of Constructing Sprinkling Filter Plant and Appurtenances.

Intercepting sewers, pumping stations and appurtenances, including a daily capacity of 340,000,000 gallons, and rising mains	$3,300,000
Septic tanks, 60,000,000 gallons' capacity, covered, including sludge disposal facilities	950,000
Sprinkling filters, 80 acres, with all appurtenances, office, laboratory, etc.	3,600,000
Settling basins, 15,000,000 gallons' capacity	200,000
	$8,050,000
Contingencies and supervision, 15 per cent	1,207,500
Total	$9,257,500

Annual Cost of Operation.

Pumping, fuel, labor, and repairs	$200,000
Supervision, analytical and clerical assistants	30,000
Care of septic and settling tanks, including sludge disposal	54,000
Care of sprinkling filters	110,000
Supplies and miscellanies	25,000
Total	$419,000

Capitalizing the operating expenses at 5 per cent per annum, there is obtained $8,380,000, which when added to the estimated construction cost makes a total sum of $17,637,500 for the sprinkling filter project.

Conclusion.

In recapitulating the substance of the foregoing inquiry and referring specifically to your instructions, summarized at the outset, we conclude as follows:

1. The examination into the sanitary situation at Chicago, so far as it is affected by sewage disposal, revealed that since removing the sewage through the drainage canal the appearance of the water of the Chicago River has shown marked improvement. As regards the hygienic quality of the public water supply there has also been an improvement, due to the progressive elimination of sewage from the lake, which elimination should be completed within a few years.

2. The latest conclusions of sanitary engineers as to the amount of dilution which is required to make sewage inoffensive, are that a dilution of 3 1-3 cubic feet per second for each 1,000 persons connected with the sewers, as provided for in the enactment of the Illinois legislature in 1889, is as low a figure as it is now possible to state. We believe that with the elimination of objectionable trade wastes and the occasional dredging of the river, this amount of dilution will be sufficient to prevent offensiveness.

3. The extension of the dilution method to the outlying territory is not the only way to preserve the lives and health of the people of Chicago. The application of this method with flows of 10,000 and 14,000 cubic feet per second, respectively, for the area tributary to the present drainage canal will serve population not exceeding 3,000,000 and 4,200,000 respectively. For greater populations, other methods of sewage disposal will be required.

4. For the Calumet area, as well as other districts, there are several methods for the disposal of sewage, as effective as the present method of dilution in preventing the pollution of the lake waters.

5. All of these methods involve intercepting sewers and pumping stations to collect and deliver the sewage at suitable sites. Septic tanks are used for partially clarifying the sewage, which may then be applied to any one of three methods of filters, viz., intermittent sand filters, contract filters, and sprinkling filters.

All of these filters, if well built and well managed, remove the suspended and organic matters so that the effluents are practically clear and are non-putrescible. The removal of bacteria by these three types of filters averages at least 98, 80 and 90 per cent respectively. Such effluents may be discharged directly into any of the water courses of the Calumet region.

6. The approximate total cost, liberally estimated, without the preparation of detailed plans, for a population of 1,200,000, are as follows:

A.—Intermittent Sand Filters.

Construction	$11,063,000
Annual cost of operation, $866,000, capitalized at 5 per cent	17,320,000
	$28,383,000

B.—Contact Filters.

Construction	$11,787,500
Annual cost of operation, $551,000, capitalized at 5 per cent	11,020,000
	$22,807,500

C.—Sprinkling Filters.

Construction	$9,257,500
Annual cost of operation, $419,000, capital at 5 per cent	8,380,000
	$17,637,500

The present population on the Calumet area of the sanitary district being less than 200,000 would naturally require but a portion of the cost of estimated works and of their operation to be expected at the outset.

Of the available methods of disposing of the sewage of the Calumet area, other than by dilution, the sprinkling filter method, being the cheapest, both in cost of construction and of operation, and accomplishing an adequate degree of purification, is clearly the most advantageous one.

Very respectfully,

RUDOLPH HERING,

GEORGE W. FULLER.'"

I will ask you whether or not the statements in that report are the statements on this subject to which you have referred in your direct examination as having been made by you in the year 1906?

Mr. Williams: I object to the form of the question. I object to incorporating in the question the report referred to, as not being proper cross-examination; and I object further on the ground that in the reports are statements referring to matters concerning which the witness has not been asked on his direct examination, and the entire question is improper as cross-examination.

Q. (Last question read.)

A. They are.

Mr. Wilkerson: Now that report appears to be signed both by yourself and by Mr. Fuller. Each one of the statements in that report on the subjects with reference to which you have been testifying today represent your own judgment on that subject, does it, your best judgment in 1906?

A. It does; each one does.

Q. Now, with reference to the disposal of the sewage from Chicago, I note that in this report of 1906 you refer to three methods, the intermittent sand filters, the contact filters and the sprinkling filters.

A. I do.

Q. And as a result of your analysis of the three different methods which are there discussed, you reached the conclusion that the sprinkling filter offers the most economical as well as the best method of handling the sewage?

A. I did.

Q. That is the substance of your conclusion?

A. It is excepting that I state other than by dilution.

Q. Other than by dilution of course. That is you were dealing there with methods which could be employed aside from the dilution method?

A. Yes, sir, but I also state that in my opinion the sprinkling filter is the best method other than the dilution method.

Q. Now, in determining the advisability of these different methods of handling the sewage of Chicago, did you in the studies which you made of this subject in connection with the preparation of the reports to which I have just directed your attention give any consideration to the question of the injury, if any, which would be inflicted upon the people who lived along the river below Chicago by diverting the sewage in that way?

A. I did.

Q. Or were you considering the question merely from the standpoint of the people of Chicago?

A. No, sir.

Q. You took that into consideration?

A. Surely.

Q. Of course it is a fact that there would be some injury inflicted on those people by the diversion of so much sewage through the Desplaines River, isn't it?

A. If the people would use the water as a drinking supply; not otherwise.

Q. That is to say it would destroy the possibility of their using the water for drinking purposes for a considerable distance below Chicago, would it not?

A. It would unless it were purified by filtration, as is done in other places. For instance, the City of Hamburg and the adjoining City of Altona, constituting together about one million inhabitants, discharge all their raw sewage into the river Elbe, and both cities take the water supply from this river and furnish it to the people after filtering it.

Q. That of course is possible. It would be possible for the people who live along the river below Chicago to get their water supply in that way, by filtering the water?

A. Yes.

Q. In determining whether or not Chicago is to be permitted to dispose of the sewage in that way, you would regard that as a fair element to be taken into consideration, would you not?

A. Yes, sir,

Q. That is to say, the injury which might be inflicted upon the people who live along the river and the difficulties they

would encounter in purifying the water, in case they wanted to use it for drinking purposes; I say that is a fair element to be taken into consideration?

A. I should hardly put it that way.

Q. Just how would you put it?

A. I would say anybody taking a water supply from a river, and I even extend that to the lakes where there is navigation and commerce, should have its supply filtered before use as a potable supply.

Q. That is to say that is your judgment, is it not, that in order that the people of Chicago should have the kind of water they ought to have, the water even now ought to be filtered?

A. I think the time will come when all cities on the lakes will filter their water supply.

Q. And in order that Chicago should be absolutely on the safe side, this filtration system should be installed now, even though the sewage is taken down the other way?

A. I should hardly think that it would be necessary at the present time.

Q. But it would be desirable?

A. It is always desirable to improve, if you have the money to pay for it.

Q. Isn't it a fact in considering as to whether or not it is necessary, there is always an element of chance as to what is in that water; that you never can tell with absolute certainty, but the only safe way is, as you say, to have the water filtered, the only absolutely safe way?

A. That is the general opinion now, apparently.

Q. Now, with respect to the extent of dilution which is regarded as reasonable, I think is the term we have been using here, the purpose of the dilution where the sewage is taken away through a canal such as is at Chicago, is to get rid of the local nuisance, as I understand it; the odor in the water and offensive matters of that kind?

A. It is, generally speaking.

Q. That is, you can have just as much sewage in the water as is possible to get into it without having the water so bad that it becomes offensive locally?

A. Well, I should want a margin of safety. I would not go so far as to just get to the place where it might make a nuisance.

Q. Allowing a reasonable margin of safety?

A. Yes. Our limit is governed by that degree of dilution where we feel sure that there is going to be no nuisance.

Q. That is the purpose of having such a large dilution?

A. Yes, sir.

Q. It is merely to get rid of the local nuisance?

A. It is also to oxidize the sewage, make it disappear.

Q. So as to take care of the people who live along the river further down?

A. So as to remove it, so as to purify it, oxidize it.

Q. Well, what is the necessity for that? I am assuming now that the people who live along the river further down do not use the water for drinking purposes unless it is filtered?

A. Well, we certainly want to have as good rivers, as good water in the rivers as we possibly can for navigation purposes and for the riparian dwellers, people living along the river. We do not wish to create an objectionable river.

Q. What I am trying to get at is just the process of reasoning by which the conclusion is reached that 10,000 cubic feet per second taken from Lake Michigan will give a reasonable dilution for the sewage from a population of three million people. I would like to get the process of reasoning?

A. The process of reasoning was this: because I had to go through it at the time, before I made this report; I collected information where I could find it in our own country and also in Europe, as to how many people could discharge their sewage into a river of known capacity, without making the river objectionable, without making it apparent that sewage was discharged into it. Now of course that information was not often obtainable, but sufficient evidence existed to find that when a certain amount of water, let us say it varied from three to seven cubic feet of water per second for every thousand persons, was discharged into this water you didn't notice it. Now, the lower figure is one that is found in larger streams. The higher figure is one that seems necessary in smaller streams and where conditions are rather unfavorable for the effect of oxidation and dispersion.

Now, with this information before us, it was concluded that for the case of Chicago four cubic feet per second a thousand persons was a proper figure. This was afterwards reduced to 3 1-3 cubic feet per thousand persons per second. Evidence obtained subsequent to making the report seemed to make it safe to allow, instead of two million and a half of people, three millions of people to discharge into the water for which we have designed the canal.

Q. Now, I think you said that during recent years there had been some improvements devised whereby this sewage can be treated so that you can diminish the dilution; I think you said by a third to a fourth, so that if these methods were used in Chicago and the sewage were treated in that way, those tanks constructed and the sewage screened—is that it?

A. No, the sewage settled.

Q. The sewage settled, the 10,000 cubic feet per second upon which the original estimate was made would take care of more than 4,000,000 people, wouldn't it, 4,200,000?

A. Yes, sir.

Q. It would take care of approximately 4,000,000, if the sewage were treated in that way?

A. Approximately; you can't tell exactly.

Q. Now, in connection with the construction of this system of sprinkling filters, you spoke about the treatment of the sewage by hypochlorite?

A. Hypochlorite of lime.

Q. Hypochlorite of lime? That being a process to be used in connection with the sprinkling system?

A. Only if you desire to destroy pathogenic bacteria.

Q. Well, what kind of bacteria are pathogenic bacteria?

A. Pathogenic bacteria are disease producing.

Q. Would you regard that treatment as essential, even where you have the sprinkling system?

A. That depends on conditions. I would say, for instance, that I would not regard it nearly as essential under ordinary conditions as such a treatment of the lake water, because what I should fear in the lake water would be the sewage from navigation.

For instance it is known that the discharge of a typhoid patient from a steamer in the lake will be drawn, might be drawn into a water supply intake, and possibly communicate this typhoid fever to those who consume this water in the city. That is entirely independent of the question of the disposal of the sewage of the city.

Q. Then is it your view that all the drinking water that is taken out of the lake should be subjected to that process?

A. To filtration, to guard more against lake pollution than against any pollution by sewage, if that is reasonably purified.

Q. Then of course with reference to the lake water, there is always the danger which comes in time of flood, when the

water is not carried away through the river or the canal but goes out into the lake, is there not?

A. I do not think that exists in Chicago, does it.

Q. Well, if it does there would be—

A. If it does, there would be all the more reason for treating the water supply with hypochlorite.

To go back again to your first question, it is of course better to treat effluent sewage from sprinkling filters with hypochlorite than not. There may be some cases where the cost is hardly justifiable, and that is the reason why I say you can't make a general answer to that question. I did recommend it, I did recommend this treatment for a city on the lake.

Q. Where this German method to which you have referred is used, is there any element of value in the sludge after it has been subjected to that treatment?

A. The value would be equivalent to garden soil, no greater.

Q. It is equivalent to so much fertile dirt?

A. Yes, although garden soil sometimes must receive a fertilizer.

Q. Certainly?

A. This sewage sludge would have to, because it has been pretty well rotted out, and that which is of fertilizing value is to a large extent gone.

Q. Just go ahead, Mr. Hering, and explain fully what your views are with reference to the value, if any, in this sludge, after it has been subjected to this German treatment about which you testified?

A. At the present time in the German cities it has a very small value. Some of the farmers take it away and pay a very small amount, but most of it is dumped as an embankment, perhaps 15 feet deep, so that it is clearly of no value in that instance.

It clearly has no manurial value, and it contains naturally the undecomposed remains of sewage matter; a lot of hair is in it, fibres, which does not make it as uniform as leaf mould. It also contains bits of wood. I should not consider it worth as much as the ordinary garden soil as it is bought.

Q. Did I understand you to say that you had made any definite estimate of the cost of constructing means for subjecting this Chicago sewage to the treatment whereby the degree of dilution could be diminished by one-third to a fourth?

A. I have not.

Q. Have you any idea on that subject?

A. I have not.

Q. Can you give us that within wide limits?

A. I have made no estimate whatever.

Q. Would it be very expensive or would it be comparatively inexpensive from an engineering standpoint?

A. No, it would not be extraordinarily expensive. The tanks would cost to erect about perhaps $1.50 per capita.

Q. So that for that expense it would be possible to provide means so that 10,000 cubic feet of water per second would take care of 4,000,000 people?

A. After adding the expense of operation, maintenance, and removal of the sludge, and so on.

Q. Which I understand is not very large?

A. I have made no estimate; it would take care of a population of about 4,000,00.

Q. Have you given any thought to this phase of this question: Assume that the people of Chicago are allowed to take 14,000 cubic feet a second out of the lake, and no more than that, and the population grows to a point where that amount taken out of the lake will not give the proper degree of dilution, as a matter of fact we are still up against this question of constructing a filtering system, are we not, ultimately?

A. I could not say, because, as we have observed in the last 25 years, we are progressing, and we may not then build works just as we would today.

There is only one certain thing, and that is that the oxygen of the air will be required to oxidize the sewage when treated on land, and the oxygen of the water will be used to oxidize sewage when it is discharged into water. Those are the two elements, I believe, that will still hold us for many hundreds of years, if not forever.

Q. Speaking from the standpoint of what we now know on the subject, if we had 5,000,00 people in Chicago today and could take only 14,000 cubic feet of water per second out of Lake Michigan, we would be face to face with this necessity for filters, wouldn't we, a filtering system? Here is what I mean: I am putting the question now on the hypothesis that the Sanitary District were today permitted to divert 14,000 cubic feet of water per second from Lake Michigan. Assume that that were the fact, and also assume that Chicago had more than 5,000,000 inhabitants today, whose sewage had to be taken care of by that 14,000 cubic feet of water per second. I say on the basis of what we now know on the sub-

ject, there would be the necessity of constructing a system of filters?

A. If Chicago had 5,000,000 population today, with the present knowledge we have, the outlying districts of Chicago would probably have to have some separate treatment for their sewage.

Q. Either that or if all the sewage were attempted to be handled in the same way, we would have to have a system of filters. I am trying to get pure drinking water for Chicago.

A. I do not understand that.

Q. I mean, the excess sewage would have to be filtered?

A. Yes, that is what I understood. The excess sewage would have to be filtered.

Q. The excess over 2,500,000 population, in the light of what we now know today.

A. In the light of what we now know today. That would be, as I think, the best method today. Regarding the filtering of the lake water, I believe that would be necessary on account of the lake pollution.

Q. That would come from such a large population?

A. Not from the city pollution; the lake pollution coming from the population on the ships in the lake, or the lake pollution.

Mr. Williams: Q. That is a different problem entirely.

A. Yes.

Mr. Wilkerson: Q. That is to say if we had 5,000,000 people in Chicago, the conditions of trade and commerce would be such that in all probability the water of the lake would be so polluted as the result of those commercial conditions, that the water should be filtered?

A. I would not like to answer it that way, because it could not be very highly polluted. I do not care to use even the word "polluted." Water has caused typhoid epidemics that was as clear as any drinking water that you have on your table. I mean that the danger of getting disease producing bacteria into your water supply from the traffic on the lake, and if you like, from shore population, will in the future make it desirable in this country, as it is already in Europe, to filter the water supplies taken from lakes.

The Swiss lakes are not polluted. Lake Vyrnwy is not polluted. They are beautiful lakes. They supply the adjoining cities of Geneva, Zurich and Liverpool with water. Liverpool does not adjoin the lake but it gets its water from the lake; and that is done simply to ensure the purity of these

waters because of the incidental, accidental pollution of disease producing bacteria.

Q. The best learning on the subject is all in favor of filtering the drinking water, isn't it?

A. That is the best thing that will ever be done today. I do not think in a thousand years anything more than that will be done.

Q. It is the most effective thing that can be done to get the best results?

A. Yes, sir. May I state something more?

Q. Certainly.

A. I was going to say in none of the cases that I have mentioned does any sewage whatever go into the lakes.

Mr. Wilkerson: I understand that.

Mr. Williams: They are separate problems, sewage disposal and water purification.

The Witness: Yes.

Mr. Wilkerson: Q. So far as Chicago is concerned, however, the problem of pure water and the problem of sewage disposal are not absolutely separate problems, are they, because if the water supply of Chicago were filtered, it would not make any difference whether the sewage emptied into the lake or not would it?

A. I do not hold that view. I should, in the case of lakes, I should hereafter as heretofore advocate either the purification of the sewage, treatment in some degree or a separation between the sewage out-fall and the water intake, that is sufficient to make a mixture practically impossible, a mixture of the sewage and the drinking water practically impossible.

Q. That is to say, taking the first method that you have spoken of, you would have the sewage treated before it comes into the water of the lake, and if that were done and the water were filtered, then you would have as a result, pure water?

A. Yes. I want to be sure that the sewage could not be detected at the water intake.

Q. Why?

A. And after that still treat the water. Because you cannot detect the pathogenic bacteria. They are diffused in the water. They may be in very clear water, and as a matter of public safety, I believe the practice of both sewage purification and water filtration should be provided for wherever expedient; not because I am in that business, but because I think so.

Q. In response to the last question, which Mr. Williams

put to you you said that even if you had enjoyed in 1887 the same light on this subject which you enjoy today in view of the advancement of the science, you would still adhere to the idea that the dilution method was the better method for Chicago. I think that was the substance of what you said?

A. That was the substance.

Q. It is true, however, is it not, that in view of the new light which we have on that subject as the result of the investigation of the last twenty-five years, it would be possible for a city like Chicago, situated as it is there on the lake, to handle this sewage problem without the construction of any such works for the dilution of the water as were constructed; I say it would be possible to do it?

A. It is possible.

Q. And that would be by treating the sewage and by the construction of a system of sprinkling filters, that would be your method?

A. That would be the method that I would advocate today.

Q. Would the cost of such a sprinkling filter plant for two and a half million people be substantially double what it would be for 1,200,000?

A. Generally speaking, yes, but local conditions might make it necessary to remove these treatment works to sections that are available for the purpose, and that might in one case—for one part of the city, might cost a good deal more than for another part of the city.

Q. But generally speaking, would the cost increase about in proportion to the extent of the population for which you wish to make provision?

A. Yes, when you get the large figures, that is true.

Q. Of course, for the smaller plants you have to add more?

A. Yes.

Q. It would be more than half when the plant was a small one, but where you deal with large figures, where you get up into the millions in population spread out over a large territory, the cost is approximately in proportion to the territory which you serve?

A. Provided the territory was equally available.

Q. Besides the cost of constructing the plant, I assume that there would be an additional cost growing out of the necessity for altering the system of sewers?

A. There would, if you propose to treat the sewage on land, and treat it sufficiently well so that it could be dis-

charged into the lake; it would require a new system of sewers for the entire City of Chicago.

Q. Did you ever make any study of the City of Chicago with a view to determining how much it would cost to install one of these sprinkling filter plants to take care of the entire sewage of Chicago?

A. Not for the entire sewage of Chicago.

Q. You made it on the basis of 1,200,000?

A. I did.

Q. I mean studying the system of sewers with a view to ascertaining how much reconstruction would be necessary?

A. No, sir, never made that.

Q. You have never made an analysis of that?

A. No, sir.

Q. But the plan is one which from the engineering standpoint is entirely feasible, I understand?

A. Well, I don't know.

Q. That is, you would not want to express an opinion without having made a study of the subject?

A. I would not because—oh, I understand with the separate system it is entirely feasible?

Q. Yes.

A. I should say it was with the separate system completely installed, it is feasible to have sewerage purification works, to receive the sewage and to purify it; but I never made a study of the cost.

Q. Now, with respect to the construction of this sprinkling filter system to take care of a population of 1,200,000 inhabitants, I notice you have a figure for a population of 300,000 and also a figure for a population of 1,200,000. Would the figures for cost for a population of say 300,000 or 600,000 run about in proportion as the cost you have given for 300,000, 1,200,000; are those large enough figures so that if you wanted to find how much it would cost to build a plant for a half million people, you could determine it with a fair degree of accuracy from your figures for 300,000 and the 1,200,000?

A. I think if you draw a curve—

Q. You are referring now to the diagram in the report to Mr. McCormick which has already been identified here?

A. Page 39.

Q. Page 39 of that report?

A. There is a curve which gives the cost of introducing sprinkling filters on the Calumet area.

Q. The sprinkling filter cost line crosses the Calumet Sag canal cost line at the population of 900,000, doesn't it?

A. Yes, sir.

Mr. Williams: I object to counsel's asking what the diagram shows. The diagram shows for itself. It is not necessary to ask the question and it is not proper in the record.

Mr. Wilkerson: Now, with reference to this estimate of cost, I think you said the figures which you had stated in your first reports would be subject to some increase, on account of the advisability of using the hypochlorite treatment. Am I correct in understanding that that was the principal element of increased cost that you had in mind?

A. You said my first reports.

Q. Or reports.

Mr. Williams: The report to Mr. McCormick.

Mr. Wilkerson: The report to Mr. McCormick.

The Witness: That is the last report.

Mr. Wilkerson: The last report. I stand corrected.

The Witness: I would today add the cost of hypochlorite treatment. Just how far I would go with that, I could not say without a study.

Q. You have made no figures?

A. No, sir.

Mr. Williams: And in addition to that you would add—what was it you just stated?

Mr. Wilkerson: I thought that was all.

Mr. Williams: No, he testified with reference to the—

The Witness: I would change the estimate by increasing it so far as the tanks are concerned for collecting the sludge. I would today make them more expensive because of their being double instead of single, for the purpose of getting non-odorous sludge.

Mr. Wilkerson: Q. What per cent. of increase would there be for these sixty million gallons capacity septic tanks?

A. I could not say without making the figures.

Q. As to the amount of increase for the cost of tanks, I understand you to say you have made no estimate on that?

A. No, excepting what I gave you, the cost being $1.50 per person.

Q. That would be, on a population of 300,000, about $450,000; that would be an increase of about $175,000 on the tanks.

Mr. Williams: That is on 300,000.

Mr. Wilkerson: Yes.

Q. On the basis of a population of 1,200,000, the revised figures would be $1,800,000 instead of $950,000 as given in the table?

A. Yes, sir.

Q. Now, as to increasing the capacity on account of climatic conditions, have you made any particular estimate as to that?

A. I have made no estimate of cost on that.

Q. Would you increase it by a percentage?

A. If the conclusion would be that the increase in the size of the beds would be 25 per cent., then that would pretty nearly indicate the increase in the cost, although I would not like to be held exactly to those figures.

Q. And these items of increase, you state, are not because the matters which they cover are regarded by you as absolutely essential, but because you think it would make the plant have a higher degree of efficiency?

A. Well I should say that it was the proper thing to do for a first class city.

Q. You would say it was a proper thing to do, but would you not say that the figures which you gave in the report in 1907 would provide a plant which while it might not be as good as it might be, would in all essential respects answer the requirements?

A. Well, at that time we thought it was a proper figure. As I stated before, I did not wish to load it with anything that might possibly be cut off or postponed because it was for the system that was to be ruled out; and I would rather be under than over in my estimate in this particular case.

Q. Referring again to this hypochlorite treatment, I understood you to say that the cost varied from $1.25 to $2.50 per million gallons; and I wanted to bring out if I could what were the elements that entered into that variation in price?

A. The reason for that variation in price is the character of the sewage. If the sewage is loaded with more organic matter, it requires a greater amount of hypochlorite. If the sewage is very clear and comparatively free from suspended matter, it requires less.

Now, I am not able to judge as to the character of the sewage that you have in the Calumet region, therefore I gave you those two figures, between which I am quite sure the amount would be.

Q. Now, assuming that the quantity of sewage which is diverted through the present drainage canal is increased to the point where there is more sewage than would be permitted by this reasonable dilution of which we have spoken, and eliminating the looks of the water, the appearance of the water and any effect it might have on navigation, what other in-

jury would result from that increase in the quantity of sewage?

A. An increase beyond this figure that I gave you as being the proper dilution?

Q. Yes, beyond the point where there would be 10,000 cubic feet of water per second for three million people?

A. Well, if you did not take out the suspended matter or sludge, then you would get a pretty good sludge deposit that would decompose, putrify, develop gases; and these gases would rise to the surface, coming out in little bubbles which you see in such cases. These would bring up little particles of light floating matter, and then you would get an offensive appearance.

Q. An offensive appearance, and any odor?

A. And very likely some odor.

Q. Any very considerable odor?

A. That would depend on the amount of decomposition that was going on, or rather I should say of this putrifaction that was going on.

Q. You would hardly say there would be very much odor unless the quantity of sewage was increased very considerable above the point which you have indicated?

A. Well, yes, sir, I am making this limit of 3⅓. I found that later on when the Massachusetts State Board of Health made similar investigations they rather tended to increase that amount, and whether that was just simply a sensitiveness of the nostrils or not, I don't know.

Q. What I am trying to do is to eliminate the aesthetic elements and get down to the elements of substantial injury.

A. That is very difficult to say, because one person will have a different judgment from another.

Now take the standard given by Massachusetts, it varies I think from 3 to 7½, a very great variation, and you can't fix that exactly by any reasoning resulting from odor. You might fix it by assuming a certain chemical analysis, we will say a certain amount of free ammonia, or a certain amount of albuminoid ammonia; but even then in my opinion, two engineers or two chemists might fix different limits. It is a matter of judgment to a large extent.

Q. Isn't it a fact that the results that would come from increasing the proportion, if I may use that term, of sewage in the water would not do substantial injury to health or property or navigation, but would be largely the injurious effect upon the appearance of the river and the odor, if any, which might come?

A. That is certainly a difficult question to answer because it is so personal. One person has a very different idea about that than another; and in dealing with this question, which has been up to me many a time, I have always thought that the only safe figure is one which goes well inside of all the opinions that are likely to be obtained; apply, as we engineers do, a factor of safety, to be sure to get inside.

Q. Be sure and have enough water?

A. Have enough water.

Q. And that is what you tried to do when you made this estimate?

A. Well, I thought I was doing that when I fixed 4 cubic feet per 1,000 people, when that report was published; but afterwards it was changed to $3\frac{1}{3}$; I think that factor of safety was taken out, to some extent.

Q. Of course so far as making the water unfit for drinking purposes or use of that kind, it would not make much difference would it because there is enough going in there now to make it unfit for that?

A. I do not think the drinking water question would cut any figure in that, because that water should not be used for drinking at all of course, without very thorough filtration.

Q. But so far as navigation is concerned, you would have to get a great deal more in to really affect navigation, wouldn't you?

A. I would not think so, since we had this discussion over here in Brooklyn. The navigation interests are objecting to some sewage in the Gowanus canal.

Q. I am referring to the condition as it is now in the drainage canal; you would have to put a good deal more sewage into it, very many times as much as goes in now before you would have any effect on navigation?

A. Well, the only effect on navigation would be a blackening of the paint of the vessels, such as occurs over here in Brooklyn, and the odor.

Re-direct Examination by Mr. Williams.

Q. Do you know what is the amount of solid matter in ordinary sewage per capita per day?

A. I can't tell you by heart. I have got lots of data at home on that subject, and I am going to publish a paper, I did want to publish it two years ago, on that subject.

We assume in our calculations for sludge treatment works about 0.007 cubic feet per capita daily.

Q. And the weight of it is about 75 pounds per cubic foot, is that what it would weigh?

A. That is what I think it would weigh, about a half a pound per person.

Q. In your answers, Mr. Hering, to the questions put to you by Mr. Wilkerson, respecting the desirability of purifying the water supply of Chicago and other lake cities, were those answers made with reference to general conditions, irrespective of the disposal of sewage, or as a matter of protection from sewage?

A. They were made irrespective of the sewage discharge from the city.

Q. And the necessity for installing purification plants as a result of the discharge from cities of the sewage out of the city is a different problem from the general desirability of having purification plants as a matter of precaution from the natural conditions arising from lake traffic and shore sewage and washings and things of that sort?

A. Yes, sir.

Q. In your opinion, would it be safe to discharge the effluent of the sewage of a population of a million two hundred thousand people into Lake Michigan, after that sewage had been treated by the sprinkling filters such as were designed and reported on by you in your report to the International Waterways Commission in 1906?

A. I think it would be safe, although today in view of the comparatively slight cost, I would add the hypochlorite treatment.

Q. I am speaking now of the filter systems that were designed and reported upon by you and Mr. Fuller to the International Waterways Commission?

A. I understand.

Q. That is the same system you reported on to Mr. McCormick?

A. Yes, sir.

Q. That is assuming no purification of the water supply?

A. Yes, sir, assuming no purification of the water supply.

Q. What percentage of organic matter would you reasonably expect to find in the effluent after it had been treated by that process; that is by the sprinkling filter process, and before it had been subjected to the hypochlorite of lime process?

A. I would have to look that up.

Q. In your opinion what percentage of bacteria is destroy-

ed by the sprinkling process, without the treatment by the hypochlorite process?

A. The usual assumption is from 95 to 99 per cent.

Re-cross Examination by Mr. Wilkerson.

Q. With reference to the percentage of bacteria removed by the sprinkling filters, what further have you to say with reference to the desirability of removing all the bacteria, and with reference to the relation of the percentage removed by some other part of the plant?

A. I will say that if you have final settling basins and expect some of the suspended matter to leave the filters for the purpose of being further purified in the settling basin that a higher percentage of bacteria in the effluent would rather be desirable than otherwise, because they would assist in the final purification.

The tendency is, however, to accomplish as complete a purification as possible in these sprinkling filters, so that no subsequent bacterial oxidation will be required in the settling basins, if they are at all put in for the purpose of turning out at all times a clear effluent. The sprinkling filters sometimes discharge a slightly turbid effluent when it is unloading, as the term is.

At the present time, the exact details of construction or operation of sprinkling filters, which is best, is not yet known and is in the process of development; with all prospects, however, of improvements being developed within the next few years.

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Adjourned.

End